A critical analysis of the defining features of problem structuring methods

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"This job is full of ups and downs. We have to make sure we celebrate the ups, and when we do that, we celebrate with pizza"

Declaration

I declare that this work is my own and that this thesis has not been submitted for degree at another university.

Abstract

This thesis seeks to explore if there is a defining philosophy, theory and methodology underpinning problem structuring methods (PSMs). PSMs are a class of qualitative Operational Research (OR) approach for making progress with ill-structured problems. The development of each of the established approaches was in relative isolation with little research cutting across all PSMs.

There are no agreed standards or characteristics for an approach to be considered a PSM. This creates a problem for the increasing number of newly developed qualitative OR approaches which share many common features with the established PSMs but are not recognised as such. To close this gap the thesis conducts analysis of the literature identifying these common features.

To understand the diversity of theory and methodology of PSMs this thesis theoretically and methodologically develops the existing qualitative OR approach WASAN and positions it alongside the existing PSMs. Bridging the gap between established PSMs and other qualitative approaches will identify the qualifying features of PSMs, how to identify these features in other approaches and how theory development in one approach can be transferred to other PSMs.

Next the thesis develops the qualitative OR approach WASAN through an action research program. The problem context is a UK Police Force who are aiming to reduce wasted time in their emergency contact centre. The researcher modelled four individual systems in customer contact using WASAN. WASAN considers how behaviour of an upstream system can increase waste production in the system being modelled. The research analysed the individual models and the interaction between models.

The research project shows how to identify the features of PSMs in an approach; the process of developing a bespoke approach into a generic approach; and, the commonality of an underpinning framework between WASAN and the existing PSMs through the transferability of theoretical contributions.

Chapter 1

Introduction

1.0 Introduction

This thesis seeks to provide a depth of understand about problem structuring methods (PSMs) through a critical analysis of their defining philosophical, theoretical and methodological features. PSMs are a class of qualitative Operational Research (OR) approaches for making progress with ill-structured problems (Rosenhead & Mingers, 2001b). Several PSMs were developed in the 1970s and 1980s which are now well established, each with their own theory and methodology. However as each PSM was developed in relative isolation there is relatively little research focussed on identifying the philosophy and theory cutting across all PSMs. To understand the diversity of theory and methodology of PSMs this thesis theoretically and methodologically develops an existing qualitative OR approach and positions it alongside the existing PSMs. Bridging the gap between established PSMs and other qualitative approaches will identify the qualifying features of PSMs, how to identify these features in other approaches and how theory development in one approach can be transferred to other PSMs.

1.1 Problem structuring methods

The first PSMs were predominately developed in the 1970s and early 1980s in response to a perceived crisis of confidence in traditional OR approaches (Kirby, 2007). The traditional OR approaches focussed on the objective modelling and optimisation of a situation (Paucar-Caceres, 2010), however McClelland (1975) argued approaches based on objective quantitative modelling are unhelpful in the types of problems typically faced by managers. Managers' problems are rarely precise and representing them in an objective model constrains the outcome of analysis to a number of results less than the actual options available. Responding to these criticisms developers of PSMs rejected objective modelling and focussed on developing OR approaches that focussed on qualitative multi-perspective representations of a situation (Rosenhead & Mingers, 2001b) where learning was the aim, not optimisation (Checkland, 1985b). The developers of these PSMs worked in relative isolation from one another focussing on the theoretical development of their own ideas and methodologies. This meant theories spanning across the different PSMs were not developed. Even papers and books presenting PSMs as a research field (such as Rosenhead & Mingers, 2001b) tended to focus on discussing each PSM in isolation rather than present an integrated study on the theory of PSMs. However there were similarities in the ways in which these approaches view: the nature of problems; the knowledge required to 'solve' these problems; the values placed upon problem solving; and, the methodology required to 'solve' these problems. Rosenhead (1989a) (later Rosenhead & Mingers, 2001) explained how the assumptions made by these methods constitutes a new paradigm of analysis for OR and collated together five such approaches in 'Rational Analysis for a Problematic World' (Rosenhead, 1989b). The PSM label was applied to these approaches in the book and so by convention they have retained the grouping and the label. To illustrate the nature of PSMs below are condensed descriptions of the original five approaches by Mingers & Rosenhead (2004 p.532) which were based on earlier descriptions by Rosenhead (1996):

SODA is a general problem identification method that uses cognitive mapping as a modelling device for eliciting and recording individuals' views of a problem situation. The merged individual cognitive maps (or a joint map developed within a workshop session) provide the framework for group discussions, and a facilitator guides participants towards commitment to a portfolio of actions.

SSM is a general method for system redesign. Participants build ideal-type conceptual models, one for each relevant world view. They compare them with perceptions of the existing system in order to generate debate about what changes are culturally feasible and systemically desirable.

SCA is a planning approach centred on managing uncertainty in strategic situations. Facilitators assist participants to model the interconnectedness of decision areas. Interactive comparison of alternative decision schemes helps them to bring key uncertainties to the surface. On this basis the group identifies priority areas for partial commitment, and designs explorations and contingency plans.

Robustness analysis is an approach that focuses on maintaining useful flexibility under uncertainty. In an interactive process, participants and analysts assess both the compatibility of alternative initial commitments with possible future configurations of the system being planned for, and the performance of each configuration in feasible future environments. This enables them to compare the flexibility maintained by alternative initial commitments.

Drama theory draws on two earlier approaches, metagames and hypergames. It is an interactive method of analysing co-operation and conflict among multiple actors. A model is built from perceptions of the options available to the various actors, and how they are rated. Drama theory looks for the ‘dilemmas’ presented to the actors within this model of the situation. Each dilemma is a change point, tending to cause an actor to feel specific emotions and to produce rational arguments by which the model itself is redefined. When and only when such successive redefinitions have eliminated all dilemmas is the actors’ joint problem fully resolved. Analysts commonly work with one of the parties, helping it to be more effective in the rational-emotional process of dramatic resolution.

Of the five approaches SSM and SODA dominated use both in practice and theoretical development with SCA more prevalent than robustness analysis and drama theory. This was shown by Munro & Mingers' (2002) survey of OR practitioners, which demonstrated gulf in percentage of practitioners that had either "used" or "heard of" the dominant approaches compared with the other approaches. In terms of theoretical development the dominant approaches had key contributions from their developers and other unaffiliated researchers. The theoretical development of the dominant PSMs focussed on individual methodologies, for example in SSM theoretical development started by carrying forward the debates from the 'crisis in OR' by advocating a move towards learning and away from optimization and how SSM achieves this (Checkland, 1985b); then in rooting the development of SSM within an action research methodology (Checkland & Holwell, 1998), then differing ways to use SSM either as an explicit external device with participants, or an internal way of thinking about a problem (Checkland & Winter, 2005). Despite continued research into these dominant approaches very little research was carried out across PSMs to critically analysis their common features.

When first presenting PSMs Rosenhead (1989) never laid out any criteria required for an approach to be considered a PSM, the research only identified a number of common characteristics (Rosenhead & Mingers, 2001a). Subsequent research has not looked to develop criteria to define PSMs either however many authors have described PSMs in general often to set a research context during the introduction of a paper. These descriptions have fallen into two main approaches, authors either focused on the characteristics of the problems PSMs address or on how PSMs seek to analyse problems.

The problems PSMs are suited to addressing have been described as pluralistic (Jackson & Keys, 1984) where multiple stakeholders have divergent views about objectives. The problems exist in dynamic and complex systems that interact with each other (Ackoff, 1979b). Churchman (1967) regards them to share many of the following properties: they cannot be exhaustively formulated as every formulation is a statement of a solution; there is no stopping rule; no exhaustive list of operations; there are many explanations for the same problem; there is no immediate or ultimate test; every problem is unique. Other authors add that problems often lack reliable data (Mingers & Brocklesby, 1997) and standard mathematical techniques are not applicable (Simpson, 1978), as problems are defined by actors social constructions (Keys, 2006) and so require constant negotiation (Pidd, 2009). Given their diversity of form and interpretation, the problems rarely fit neatly into rigid analytical frameworks (Checkland, 1983). Therefore PSMs must take a more flexible approach in modelling these problems.

Descriptions of how PSMs manage problems focus on how they build models of situations (Franco, 2013), where a model is a representation of a situation that supports negotiation, or develops new understanding. The models are qualitative (Ackermann, 2012) often representing differing worldviews (Mingers, 2011). PSMs reject reductionism (Ackoff, 1979b) where individual elements are optimised independently of the whole. Instead they manage complexity (Rosenhead, 2006) by taking a holistic approach, seeing problems as systems where elements are connected by interrelationships rather than static snapshots (Senge, 1990). Thus PSMs explore systemic issues (Midgley et al., 2013) and discover emergent system properties (Checkland, 1981). They aim to build shared understanding and commitment across stakeholders (Ackermann, 2012) through facilitation (Franco & Montibeller, 2010), participation (Rosenhead, 1996), stimulating dialogue (Mingers & White, 2010) through a structured decomposition of issues. A social process of learning takes place through which actions are agreed (Pidd, 2009).

These two types of descriptions although sufficient to provide context to readers of journal papers do not provide a comprehensive understanding to answer what seem a relatively simple question of “What is a PSM?”. As Ackermann (2012) writes we know the characteristics of PSMs but we do not know which approaches do and do not apply. This thesis seeks to close this gap through a critical examination of the defining philosophical, theoretical and methodological features of PSMs.

To understand how PSMs features might be understood the research considers nine qualitative approaches developed since 2000 to see how their developers have positioned them in relation to PSMs and how this positioning has been justified.

1.1.1 Positioning an approach as a PSM

Westcombe, Franco, & Shaw (2006) reviewed the state of PSMs over 30 years from 1970 to 2000, they suggested over this period the development PSMs relied heavily on a few ‘gurus’. As a result of this the field begun to stagnate, dominated by few approaches with a lack of new ‘grassroots’ PSMs to drive the field forward. To remedy this they suggest that post-2000 researchers should focus on the development of new PSMs to unlock the rigor mortis that was setting in and drive forward a field whose development had ‘stalled’. Since 2000 this project has identified nine ‘new’ wholly or partly qualitative OR approaches have been published in ‘The Journal of the Operational Research Society’ and ‘The European Journal of Operational Research’. Some of these have been completely new, perhaps drawing from existing PSMs and the developers experience such as issues mapping (Cronin, Midgley, & Jackson, 2014), others such as DPSIR have been developed elsewhere and are now presented to the PSM community due to their similarly of approach with existing PSMs (Gregory, Atkins, Burdon, & Elliott, 2013).

These new approaches have faced significant problems when justifying where they sit in relation to the existing PSMs and wider OR. PSMs as part of OR which itself is part of a set of wider management tools. However the boundary of PSMs is not established or understood and therefore justifying that any of these new approaches sits within the PSM boundary (or indeed outside the boundary) is cannot be achieved.

The lack of understanding about what is a PSM presents a problem for the developers of these new approaches. Consequently when presenting their work each author had to compare and justify their approach against their own boundary for PSMs. Thus it was down to journal reviewers to decide if the argument was convincing enough to merit publication and subsequently the method being regarded more widely as a PSM. Table 1 summarises the nine qualitative or partly qualitative approaches along with the naming convention and reference to the original paper. Of the nine approaches four were classified as ‘Soft OR’, three as ‘PSMs’, one as ‘a facilitated methodology’ and one as a ‘context specific PSM’. Upon reading these papers it is clear they all demonstrate an attempt to rectify some of the criticisms aimed at quantitative OR during the crisis of confidence in the 1970s which led to the initial divergence of OR and emergence of PSMs. However what is unclear is if each approach demonstrates the features required for them to be considered a PSM, indeed it is still unclear if there are enough common features from the established PSM for them to be considered a group of approaches.

Figure 1 shows PSMs as a sub-category to OR with OR part of a wider set of management tools. Based on the disparate labelling of the nine OR approaches from Table 1 it seems the new approaches have been unable to consistently make the case to sit neatly in the PSM category. Although they all demonstrate some of the features of PSMs research have been unable to fully show these approaches belong within the PSMs category as a clear boundary does not exist. This research project uses the term ‘fringe PSM’ to describe these such approaches that demonstrate features of PSMs but have not been able to clearly, methodologically and rigorously show they belong alongside the existing PSMs. To progress an approach into the PSM category will require a deeper more rigorous understanding about the common features of PSMs with which fringe PSMs can be compared.

Approach	Naming Convention	Reference
FAcT-mirror	“The Fact-Mirror method shares some similarities with another major category of approaches to resolve complex problems: ‘Soft’ operational research” (p.700)	(Cardinal, Guyonnet, Pouzoullic, & Rigby, 2001)
General morphological analysis	“This article gives a historical and theoretical background to GMA [general morphological analysis] as a problem structuring method” (p.792)	(Ritchey, 2006)
Visioning choices	“This paper describes the development of a participative visioning methodology, Visioning Choices, which is placed within the family of problem structuring Methods” (p. 557)	(O’Brien & Meadows, 2006)
WASAN	A facilitated methodology for structuring a waste minimisation problem (title)	(Shaw & Blundell, 2010)
DPSIR	“The case has been made that the Imagine methodology provides the potential for traditional quantitative methods and alternative PSM approaches.” (p.358)	(Bell, 2012)
DPSIR	“… the approach to be defined as a PSM for use in a particular applied context.” (p.563)	(Gregory et al., 2013)
Meta-synthesis approach; Wuli–Shili–Renli; Experimental policy research methodology	Soft OR in China (title)	(Li & Zhu, 2014)
Issues mapping	“This paper introduces ‘Issues Mapping’, a problem structuring method.” (p.145)	(Cronin et al., 2014)

Table 1 ‘New’ qualitative approaches published in OR journals between 2000 & 2014

The case can only be made for a fringe PSM to be included alongside the established PSMs by achieving the central goal of this thesis, ‘a critical analysis of the defining philosophical, theoretical and methodological features of PSMs’. One element of this understanding is to define the central features of PSMs which can then be used as the comparison for the fringe PSMs. Without such clear boundary we risk false positives, where non-PSMs are accepted into the field, which could lead to dilution of the field and scope creep leading to a loss of identity; and, rejected positives, where actual PSMs are rejected, which could discourage potential members of the community presenting their ideas as PSMs, leading to a loss of variety and potentially stagnation. To investigate these issues the research project will develop the fringe PSM WASAN to a point where it can be positioned as a PSM. Each step this project takes towards this goal will provide opportunities to critically asses the philosophy, theory and methodology of PSMs.

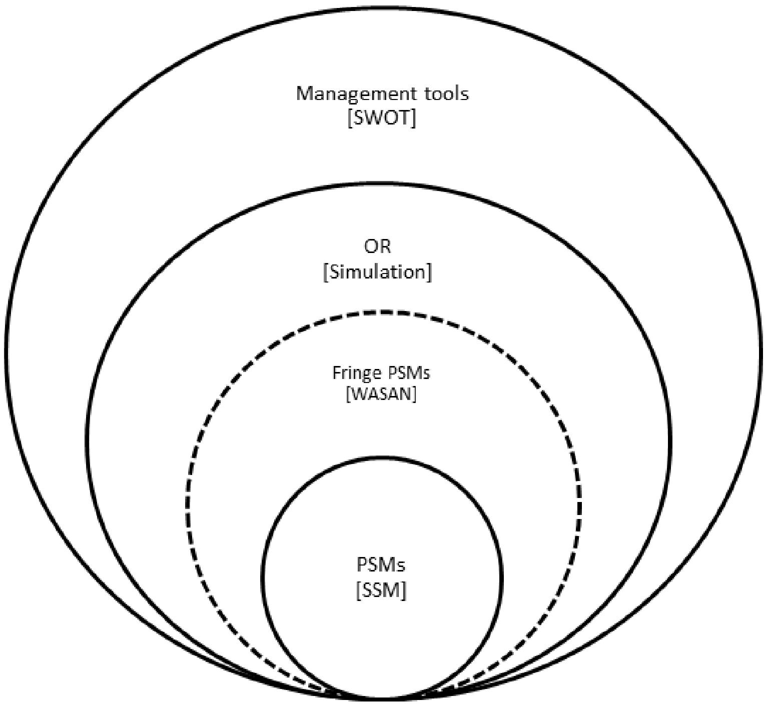

Figure 1 Placement of PSMs and fringe PSMs within OR

1.1.2 Developing WASAN

The inability to say with confidence if an approach is a PSM or not a PSM points to a lack of depth in the understanding about the theory and methodology of PSMs. The research community still have questions relating to what makes an approach a PSM as there has not been a critical examination of PSMs to understand their defining features. Even if the correct criteria can be identified there is no understanding on how to use these defining features to show if an approach is a PSM or not. Answering these questions will provide a better understanding about the broader theory and methodology of PSMs. To do this the thesis will develop a fringe PSM to a point where it can be positioned alongside the existing PSMs. This will force the researcher to confront and critically analyse the issues about PSM philosophy, theory and methodology outlined above which will lead to a deeper understanding of the philosophical, theoretical and methodological features of PSMs.

To achieve this aim WASAN will be utilised as an example to develop and position as a PSM to discover more about the theory and methodology of PSMs. The original development of WASAN drew from existing PSMs such as SODA and SSM embracing qualitative modelling techniques to explore a system. The influences of the existing PSMs and the qualitative nature of WASAN clearly mean it shares some features with PSMs and therefore is a good candidate for critical analysis. However the narrow focus in the original development of WASAN means the approach is still not fully understood or exploited and will require further methodological and philosophical development before it can be considered as a PSM. Hence the research is yet to identify a suitable definition of the PSM boundary for WASAN to be compared against. Exploring these issues for WASAN will yield knowledge and a critical understanding for PSM philosophy, theory and methodology.

The thesis first will determine the critical features of PSMs by conducting a literature review of PSM theory identifying the key common characteristics of PSMs. These characteristics will then form the starting point for the boundary of PSMs as shown in Figure 1. It is generally accepted that PSMs are generic enough to be applicable to a wide range of problem contexts, for example Mingers & White (2010) review of the contribution of PSMs found they have been used in context including health (Hindle & Braithwaite, 1998; Kotiadis & Mingers, 2006), environmental agriculture (Bunch, 2003; Kayaga, 2008) and supply chain and production projects

(Hipkin & De Cock, 2000; Ormerod, 1999). Therefore for WASAN to sit alongside the PSMs this research project must show generic applicability of the approach beyond nuclear by deploying the approach in a new problem context. Critical analysis of this development may identify the features required by an approach for it to be generically applicable in multiple contexts. An action research study of WASAN deployed in a UK Police Force shows significant development removing context specific elements and replacing them with elements that were more widely applicable to different contexts. Next the research project will compare WASAN against the characteristics that mark the boundary of PSMs as identified in the four pillar framework to see if WASAN demonstrates all the required features of PSMs. This will help to identify how to operationalise the framework and test its functionality in practice.

The final area for critical examination examines how philosophical, theoretical and methodological developments in one approach can draw from and impact the other PSM approaches. Ackermann (2012 p.652) writes that each PSM "has been extensively developed – not only in terms of their ability to support decision makers but also in terms of their contribution to (and support from) theory." Therefore for WASAN to sit alongside the existing PSMs the approach will have to show the same rigour in development and ability to contribute to PSM theory. In the study of the UK Police Force the research project modelled multiple operational units from Customer Contact. WASAN models the flow of waste from and to channels that are upstream and downstream from the modelled system. If these upstream and downstream systems are also modelled using WASAN there would be a collection of interconnecting modelled systems which reference each other. To represent the interconnections between these models the project draws inspiration from the viable systems model (VSM) (Beer, 1981) and the notion of recursion. Recursion states, that each system is "embedded in other more comprehensive systems” (Leonard, 2000 p.711). This helps modellers to represent the relationships between different units or systems. As it is difficult to represent the hierarchal separation of multiple systems in a single model a VSM model presents one layer of the modelled system including the connections to higher and lowers recursive levels (Tejeida-padilla & Badillo-pin, 2010). Where VSM looks at vertically interdependent models WASAN was modelling units on the same hierarchical plane, so instead of being vertically recursive these models are identified as horizontally recursive. This allowed simultaneous representation of different models using the same modelling conventions. Representing these models side-by-side the project was able to show horizontal interdependence across models and emergent properties of the expanded system at a meta-systemic level. WASAN contributing to PSM theory further strengthens the claim that WASAN sits alongside the existing PSMs and provides further understanding of the defining features of PSMs.

1.2 Motivation of the researcher

This thesis benefits greatly from the two years the researcher spent working full time within a UK Police Force during their PhD research. Working with the police gave the Ph.D. candidate the opportunity to implement a range of problem solving approaches in the Police Force. These approaches embraced the complexity the Police encountered on a daily basis by structuring problems in a way that accounted for different perspectives and developed recommendations which were politically feasible. The time embedded in the organisation was followed by a further two years thinking critically and reflecting on this experience to theorise and write up the specific contributions to knowledge based on the rich data set gathered. Below the thesis introduces the context of the first two years along with the inspiration for the Ph.D.

The first two years of this Ph.D. was funded by an ESRC Knowledge Transfer Partnership (KTP). A KTP is a relationship formed between a company and a University which facilitates the transfer of knowledge, technology and skills to which the company partner currently has no access. Each partnership employs one or more recently qualified graduates to work in a company on a project of strategic importance to the organisation, whilst also being supervised by the University. The specific aims of KTPs vary from partnership to partnership however in general they aim to: facilitate the transfer of knowledge through projects from a company and an academic institution; provide company-based training for recently qualified; enhance business-relevant training and research undertaken by the academic institutions and; increase the interaction between businesses and academic institutions, and awareness of the contribution academia can make to business development and growth (Technology Strategy Board, 2014).

The specific aims of the Police Force for the KTP were to reduce annual expenditure within the Customer Contact Department while improving service delivery to the public. Customer Contact includes the Contact Centre, Crime Recording and the Front Office Network. The Contact Centre is comprised of a Switchboard (who answer and route all incoming non-emergency calls to the organisation), Call Handlers (who take emergency and non-emergency calls for service), Controllers (who dispatch Police Officers to calls for service). Crime Recording is comprised of Crime Desk (who take reports of historic crime over the phone and carry out low level investigations into these crimes) and Crime Admin (who record all crime reports as per national reporting standards). The Front Office Network is comprised of 12 front offices around the county; these are contact points where a member of the public can access a policing service. Drawing on an Operational Research (OR) background the Ph.D. candidate provided the analytical function to a project team who were tasked with reducing overall expenditure within the Customer Contact Department. From the outset of the project the researcher saw how complex the problem situation was, the interaction of multiple stakeholders internal and external to the Police Force rendered over reliance on objective modelling approaches ineffective. As a result when assessing the problem situation the researcher drew on inspiration from the qualitative OR approaches as they are more able to manage the complexity in these situations. In total the KTP project was responsible for annual savings of £819,000 from Customer Contact.

During informal discussions with staff from Call Handling the researcher identified that staff thought a lot of the calls they receive are not police matters and therefore ‘waste their time’. Discussing this during supervisory meetings identified the qualitative OR approach WASAN (Shaw & Blundell, 2010) as a possible modelling approach, WASAN seeks to reduce the impact of waste from upstream systems by mappings how and where waste enters the system in focus from upstream systems. Through further informal discussions initial data was gathered to identify if WASAN was appropriate and feasible to use within the UK Police Force. These early discussions identified that WASAN could be useful to Call Handling however as it was untested outside of the initial development context it would require significant development to work within the police context. Modelling Call Handling using WASAN was discussed with the Customer Contact Manager who has responsibility and ownership of the system. They thought modelling Call Handling with WASAN would add value for them and therefore be an impactful piece of research. WASAN was therefore selected as the analytical methodology under consideration in this research project. Practically the approach fitted the problem, theoretically the approach had avenues of development.

To understand what development was required of WASAN the projects scope was expanded beyond the UK Police Force to identify if there was a common philosophy, theory and methodology of PSMs, this would enable WASAN to be developed to the same standards and requirements as the existing PSMs. To understand these requirements the researcher reflected critically on the characteristics and features of the current PSMs. Knowledge of these features was used to aid the development of WASAN and apply it within the Police context. Finally knowledge from the study was expanded to draw theoretical contributions about PSMs.

1.3 Contribution of thesis

To achieve the central aim of providing a critical analysis of the philosophy, theory and methodology of PSMs, this thesis will use WASAN as a tool to explore PSMs. In doing so the thesis will answer four research questions (RQ):

RQ1. What are the defining philosophical, theoretical and methodological features of PSMs?

RQ2. How can PSMs be developed into suitably generic approaches applicable in multiple problem contexts?

RQ3. How can an approach show it has the defining features of PSMs?

RQ4. Can philosophical, theoretical and methodological contributions identified in one PSM be shown as relevant in others, thus showing a common framework?

In answering RQ1 the thesis makes the first contribution to theory. The thesis *develops a framework to assess what is a PSM* (Contribution A). Currently no such framework or accepted definition of PSMs exists, so developing one is critical in determining if an approach can be considered a PSM. The framework builds on the assertion that PSMs constitute a different paradigm of analysis to traditional OR (Rosenhead & Mingers, 2001a) and so make different assumptions about ontology, epistemology, axiology and methodology (Guba & Lincoln, 1994, 2005). Therefore to delineate PSMs from non-PSMs the framework asks 15 questions of an approach based on these philosophical assumptions as ‘four pillars’.

Second, to answer RQ2 the thesis *presents the structures and features required for an approach to be considered generic identified during the methodological development of WASAN* (Contribution B). This is based upon a study at a UK Police Force where WASAN was developed from the initial bespoke approach to a generic approach that was applicable in a new problem context.

The study also provides the information required, to answer RQ3 *with an application of the framework* [from Contribution A] *to WASAN how the four pillar framework can be operationalised in practice* (Contribution C). This will show if WASAN has the features defining features of PSMs.

To answer RQ4 the thesis identifies that WASAN used a new way of representing how interdependent functions can be represented across multiple qualitative models using recursion. The notion of recursion is taken from the qualitative modelling approach VSM where hierarchically interdependent systems are represented at different hierarchical levels where lower order systems are nested within higher order systems. In VSM recursion shows the interdependence between system and gives an elegant representation of organisations (Jackson, 2003). In the WASAN study recursion is shown horizontally not vertically. As shown in the discussion, recursive model building is also applicable to the existing PSMs. This is a new contribution to PSM theory and so further cements the justification of WASAN alongside the established PSM approaches as theory developed in WASAN is applicable to other PSMs. Previous examples of WASAN focussed on building a single model of one situation, this action research project builds four separate models of linked units within the police force. The research project shows how the notion of recursion can be used to represent these four systems, their interactions and the meta-systemic issues. The research project *shows the commonality of PSM philosophical, theoretical and methodological assumptions by showing broader applicability of contributions made in one approach to the established PSMs* (Contribution D).

Thus, the four contributions made by this thesis are:

- Contribution A: Develop a framework to assess what is a PSM – (RQ1).
- Contribution B: Present the structures and features required for an approach to be considered generic – (RQ2).
- Contribution C: Identify how the four pillar framework can be operationalised in practice – (RQ3).
- Contribution D: Show the commonality of PSM philosophical, theoretical and methodological assumptions by showing broader applicability of contributions made in one approach to the established PSMs – (RQ4).

Below the structure of the thesis is presented showing how the four Research Questions are answered by making the four contributions to theory and practice.

1.4 Structure of thesis

1.4.1 Introduction

This chapter has briefly introduced the motivation of the researcher and the main aim of the thesis to position WASAN as a generic problem structuring method. It has presented the four research questions to be addressed by this thesis.

1.4.2 Literature review

Chapter 2 has four aims; first providing context to the development of PSMs by giving a perspective on the overall development of OR. Understanding where PSMs sit in relation to the wider field gives a better understanding on how to differentiate PSMs from non-PSMs. Second, the literature review builds a framework to delineate problem structuring methods (PSMs) from non-PSMs (contribution A). The second section of the literature review (the framework) is largely based on a paper submitted to the European Journal of Operational Research which has been invited to Revise & Resubmit the manuscript after addressing reviewers' comments. The reviewers' comments (quoted in part below) showed the degree to which they think this framework provides a contribution to knowledge.

"This paper addresses a significant problem that has largely defied attempts at clarification or resolution over the years. The use of the axiology/ ontology/ epistemology/ methodology conceptual system is an ingenious way to attempt to break the deadlock." (Reviewer #1)

"An interesting paper and a useful focus, the topic is relevant to operational researchers and the development of such a framework will be a valuable tool in taking the problem structuring methods area of research further." (Reviewer #2)

Third, the literature review introduces the qualitative OR approach WASAN and how the approach was developed. The review explores and captures the philosophy of WASAN, this acts as a guard to ensure the process of developing WASAN does not distort its original philosophy.

Fourth, the literature review introduced the concept of recursion as a way of conceptualising the relationship between different systems. This concept is built upon in the discussion in answering RQ4.

1.4.3 Methodology

Chapter 3 reviews the methodology through which the four research questions were explored. The methodology is structured around Saunders, Lewis, & Thornhill (2012) research onion. The chapter discusses the philosophy, approach, methodological choice, strategy, time horizon and techniques and procedures used to answer the research question. It also presents the context of the research project to familiarise readers with the Police Force setting. In this way it lays the foundations for presenting the action research project and the findings.

1.4.4 Findings 1: Development of the WASAN methodology

Chapter 4 starts by presenting a study of WASAN in the *Call Handling* function of a UK Police Force. The chapter then discusses how WASAN was developed from a single use methodology in its first use by Shaw and Blundell (2010) to a more generic approach that could be used in the police force (RQ2). Next the chapter uses the study to identify the 15 features of PSMs from the four pillar framework in WASAN (RQ3).

1.4.5 Findings 2: Modelling the expanded system

Chapter 5 identifies a new theoretical contribution to the underpinning assumptions of PSMs. The chapter identifies how it is possible to increase understandings of a system by expanding the boundary of analysis and modelling other systems in the meta-system. This draws from the doctrine of expansionism (Ackoff, 1979a). Three further systems from the UK Police Force are modelled, Switchboard, Crime Desk and Crime Admin. The chapter identifies how modelling the expanded system can identify the relationships between models on the same hierarchical plane. This sets up the answer to RQ4 where the transferability of this contribution to the established PSMs is tested.

1.4.6 Discussion

Chapter 6 discusses the wider implications of the contributions beyond the thesis. The findings from the research questions lead to the development of eight Discussion Points. These points are considered in light of the existing literature to show the contribution to theory. It shows that RQ1, RQ2, RQ3 and RQ4 have been answered in the context of the data and the existing body of literature.

1.4.7 Conclusion

Chapter 7 draws together the strand of the thesis to show the contributions are substantial. It also identifies future research opportunities and potential future papers based upon the gaps this thesis identifies.

1.5 Summary of Introduction

This chapter has introduced and framed the research questions that will be addressed by this thesis. It also identifies the motivation of the researcher and thereby provides some context for the project. Finally the structure of the thesis is identified.

Next, Chapter 2 shows the theoretical context of the thesis focusing on the development of OR, PSMs and WASAN.

Chapter 2

Literature Review

2.0 Introduction

The central aim of this thesis is to critically analyse the philosophy, theory, and methodology of PSMs. This is achieved through the theoretical and methodological development of the fringe PSM WASAN into a generic problem structuring method. This process of development compels the researcher to ask and answer pertinent questions regarding the nature of PSMs, as well as what is common across their philosophy, theory, and methodology. The learning from this process will then be extracted and developed into contributions to the theory and methodology of PSMs. To critically question the philosophy, theory, and methodology of PSMs this thesis poses and answers four research questions: First, the thesis asks, "*What are the defining philosophical, theoretical, and methodological features of PSMs?*" (RQ1). Second, through the development of WASAN in an action research project the project asks, *"How can PSMs be developed into suitably generic approaches applicable in multiple problem contexts?"* (RQ2). Third, the framework from RQ1 is applied to WASAN to ask, *"How can an approach show it has the defining features of PSMs?"* (RQ3). Fourth, the thesis aims to develop a new PSM theory with WASAN and asks, *"Can philosophical, theoretical, and methodological contributions identified in one PSM be shown as relevant in others, thus showing a common framework?"* (RQ4).

This chapter provides the theoretical context for the central aim of this thesis—that is, to critically analyse the philosophy, theory, and methodology of PSMs. To contextualise this process the PSM and related literature is reviewed. This chapter begins by introducing the inception of Operations Research (OR) in the

1930s and then exploring the positivist assumptions underpinning these early OR approaches. The quantitative roots of OR are explored as the field developed and proliferated into industry and universities. By the 1970s, the use of quantitative OR became more widespread; however, limitations were identified in its applicability to the strategic problems of the day, which led to disillusionment with quantitative OR by some authors and practitioners. This was labelled the 'Crisis in OR', which can be categorised by a divergence of opinions regarding the nature of problems and how best to solve them. Some researchers and practitioners were disillusioned by the positivist assumptions underpinning quantitative OR, which culminated in the divergence of PSMs from the existing set of OR approaches. This difference in opinions called for a new paradigm of analysis (Rosenhead & Mingers, 2001a) making differing assumptions regarding ontology (the form and nature of reality and what can be known), epistemology (the nature of relationships between the knower and what can be known), axiology (what is valued in terms of the research process for generating knowledge), and methodology (how the knower can find out what can be known) (Guba & Lincoln, 1994, 2005). This point of divergence is explored to understand what common philosophical, theoretical, and methodological foundations were laid down for PSMs. Understanding this point of divergence is critical for understanding the development context for the PSMs that were established in the 1980s and the extent to which they were developed with common underpinning assumptions.

Second, the literature review focuses on RQ1; the different ways in which PSMs have been categorised and defined are explored, followed by an investigation of the existing PSM literature to understand the common defining features of PSMs? These features are organised into a framework which forms the basis for answering RQ1. Therefore, the literature review does not only serve the standard function of a literature review by setting the context for future theory-building and demonstrating knowledge of the existing theory but also contributes to theory by developing a framework by which to judge if an approach exhibits the common features of PSMs.

To answer RQ2, the process in which WASAN is developed into a generic methodology is evaluated; this is done by applying WASAN in an action research project at a UK Police Force. To understand how WASAN can be further developed, this chapter reviews the original development context of the approach. WASAN was originally developed in the nuclear industry where there was demand for an approach to minimise avoidable waste within a nuclear processing facility. The review considers both the underpinning philosophy of WASAN and the original approach to development to provide an understanding of how WASAN may be developed into a generic methodology during this research project. To answer RQ3, the thesis operationalises the framework developed in RQ1 to understand if WASAN as applied in the UK Police Force exhibits the features of PSMs.

In answering RQ4, this thesis seeks to identify what new contributions WASAN makes to the theory of PSMs. In an attempt to show that WASAN and PSMs share a common framework, this research question aims to make a contribution to that framework and then show the transferability of that contribution from the framework to the established PSMs. The further study at the UK Police Force models the expanded system, thereby combining the multiple horizontally related system models to identify the interdependency across a meta-system. The similarities between this method and the notion of recursion (Beer, 1981) prompts the researcher to consider if this type of model building is actually a new type of recursion. Consequently, the project has reconceptualised how recursion can be used to represent multiple horizontally interdependent modelled systems and their interactions. This model building approach is then tested in some established PSMs in the Discussion Chapter to assess the transferability of the contribution. This

Literature Review contextualises recursion in its broader sense, which is built upon in Chapters 5 and 6.

2.1 Emergence and development of OR

To critically understand the philosophy, theory, and methodology of PSMs, this thesis examines the initial development of OR and PSMs. PSMs diverged from traditional quantitative OR methods due to a crisis in confidence from some members of the academic community in traditional OR's ability to support the types of increasingly important problems in a service economy (Sadler, 1978). This led to these researchers changing the fundamental assumptions which underpin how problems should be 'solved' (Dando & Bennett, 1981). Understanding the extent to which the change in these assumptions was formalised at the point of divergence will help to identify if PSMs share a common philosophy, theory, and methodology.

The emergence and development of OR was spurred by the practical needs of users and clients; this development context can be categorised as opportunistic, where a practical need is identified by a research community which leads to methodological advancements to help answer a new type of problem. This behaviour was seen during the initial emergence of traditional OR in the 1930s, the emergence of problem structuring methods in the 1970s, and the emergence of a new set of problem structuring methods from the 2000s onwards. This opportunistic approach to development in PSMs implied that a set of new approaches were developed to make progress with complex problems; however, common philosophical, theoretical, and methodological assumptions across PSMs may not have been explicitly established as developers were concerned with the development of their own approaches. A brief historical perspective of OR and PSMs is now given to illustrate this development context.

2.1.1 Traditional OR

The roots of OR have been traced back to the British pre-World War II preparations. The British military were seeking to use the 'scientific method' to provide information to decision makers regarding operational matters. One account of the first such use of OR was provided by Williams (1968) in the discussion on the positioning of radars in 1937. Radars were developed as part of military research and development and the Air Force were now looking at how best to use it to intercept and destroy enemy aircraft. While most scientists continued to engage with the normal work of research and development and the design of radar equipment, a new team was beginning to ascertain how to best use radar. The term 'Operations' had specific meaning within the military and so 'Operational Research Section' was used on organisational charts to distinguish between the new kind of work related to operational matters and the normal work of research and development scientists. It is estimated that the use of radar in the Battle of Britain increased the effectiveness of the British air defence system by a factor of 10, and that OR increased its efficiency by another factor of 2 (Fortun & Schweber, 1993). Of course, this claimed factor-of-20 increase in efficiency cannot be verified; however, it demonstrates the confidence military personnel placed in OR and its input in wartime planning.

During the War, the use of OR spread across the British military and then to the US. Eventually, it became an integral element in the planning of major campaigns. Projects were varied but accounts from the Navy discuss OR teams working on problems such as destruction of the German runners in the South Atlantic, optimal size of large convoys of ships in the Atlantic, the best allocation of resources between producing merchant ships and anti-submarine escorts, and the effectiveness of bombing raids by a large number of aircrafts (Crowther & Whiddington, 1947). The integration of OR into the war effort implied that, by its conclusion in 1945, researchers were keen to apply the methods and techniques to industry and organisational problems. Other authors have published further examples of OR before and during World War II (see McCloskey, 1987a, 1987b, 1987c).

By the end of World War II in 1945, the power of OR was established under wartime conditions and had an identity. Goodeve (1948 p.584) described OR as "the use of scientific methods in providing executive departments with a quantitative basis for decisions regarding the operations under their control". Here, the definition focuses on the scientific method as a basis for decision making. Subsequently, other scholars moved away from this focus on a set of tested approaches applicable to practical problems. For example, Morse & Kinball (1951) describe OR as the development and application of analytical theories of action which, when tested by development, can be used to predict the probable results and cost of action within specific limits of error.

Post-war, this set of OR approaches translated across to managerial problems beyond war. In the UK, administrators saw the similarities between the problems faced in running large industrial enterprises in peace-time and managing the various units of the military in war-time and attempted to use the same approaches to solve a new set of problems facing them (Rosenhead & Thunhurst, 1982). The methods of "OR (developed for wartime) made the administration of larger scale enterprises more tractable" (Leslie, 1976 p.173). "From the 1950's onwards, powerful new mathematical techniques were developed to solve recurrent problems with particular structures, often using the power of electronic computers." (Rosenhead & Thunhurst, 1982 p.114). These approaches were founded on a positivist view of the world and problem solving. Positivism is generally regarded to concern research practices following the 'scientific method'. While this can have slightly different interpretations, Bryman (2004) identifies five foundations of positivism. First, only phenomena confirmed by the senses can genuinely be warranted as knowledge (phenomenalism); second, the purpose of theory is to generate hypothesis that can be tested and that will thereby allow explanations of laws to be assessed (deductivism); third, knowledge is arrived at through the collection of facts that provide the bases for laws (inductivism); fourth, science must be (and presumably can) be conducted in a way that is value free (objectivism), and; fifth, there is a distinction between scientific statements and normative statements, believing that the former are the true domain of science. The impact this had on problem solving for OR implied that the researcher was removed from the research process, and phenomena which needed to be understood were observed and modelled with quantitative representations. These models could be manipulated to produce answers which were 'correct' according to the model—that is, the situation could be solved with an 'optimal' or near 'optimal' answer. These OR approaches could produce the 'best' solution with a given set of complexities and constraints. Of course, the major problem with this approach of solving a model is the question of whether the model being 'solved' is a true representation of the reality it is meant to be representing. This is identified by Ackoff (1977) when he discusses a review he was asked to conduct of a large quantitative OR project where 'many' constraints and variables were included in the model to identify the optimal solution. Through their own evaluation, the project team used the model to compare the optimal solution with managerial decisions. This identified that their optimal solutions significantly outperformed the actual decisions taken. Ackoff (1977 p.1) identifies three problems with this approach; the most pressing is that, "The optimal solution of a model is *not* an optimal solution to a problem unless the model is a perfect representation of that problem."

2.1.2 Crisis of confidence in OR

The need for academic consideration of alternative paradigms to quantitative OR emerged in the 1970s when the 'Crisis in OR' was originally raised (Thunhurst, 1973). There was a growing dissatisfaction with the applicability of OR to strategic and social problems faced by industry at the time. The crisis reflected a dip in confidence of some practitioners and academics in the ability of OR to be useful in 'solving' the important problems of that time. This was the manifestation of several converging factors, which have been eloquently described by Kirby (2000, 2007). The emergent themes from the literature concerning the Crisis in OR seem to be characterised by an increasing chasm between practitioners' use of OR and university-based teaching and research into OR, increasing importance of social problems faced by organisations, and the perception or realisation that the assumptions underpinning quantitative OR were ill-equipped to deal with these new problems.

The development of OR within universities had moved away from engaging with real world problems. "While we are training our students to use mathematical theory and techniques to solve well-formulated problems, we too often ignore the fact that problems of the real world do not present themselves in such well-formed structures" (Borsting, 1987 p.790). This led to these techniques being taught "without any recognition of the subsequent uses to which they might be put by OR workers" (Simpson, 1978 p.525). Morse (1976) commented that an OR textbook more closely resembles advanced mathematics than a physical science one. Alternative systems approaches were still not understood by academics, and despite proven analogues of success such as the RAND Corporation they were not integrated into educational programmes (Miser, 1987). This was despite calls made much earlier by Churchman (1970) to expand OR education. Pierskalla (1987) suggested that the reason a narrow focus of OR prevailed within universities was that in academia, tenure is based on producing many publications quickly; therefore, the temptation is to make small advances within the limits of the accepted paradigm—in this case, positivist OR focussing on quantitative modelling.

Quantitative OR was also easier to teach as mathematicians were able to codify mathematical techniques and reproduce them in educational programs. However, this quantitative approach had its drawbacks for practitioners, clients, and the reputation of OR. A survey of members of Operations Research Society of America reported by Balut & Armacost (1986) found that for every member conducting research, three others were working in applications/practice. However, the composition of the research published in OR at the time was mainly focussed on theoretical development. One of the findings of the survey was a call to increase the number of papers based on practical applications at the expense of theoretical work. It is evident that the type of research undertaken in the name of OR was moving away from the problems that practitioners were facing thereby leading to a growing chasm between OR development within universities and practitioner uses.

The perceived divorce between theory and practice led to a perception that OR was unable to deal with a new type of emerging problems, which were rooted in social interaction. Sadler (1978) suggested that in Britain there was a move away from an industrial society, where manufacturing efficiency was the most pressing question in OR. Therefore, for OR to survive, it needed "recognition that problems in the real world are 'messy wholes'. They have quantitative and qualitative aspects, logical and irrational components, their technical, economic, social dimensions" (Sadler, 1978 p.6). These new types of problems were described as 'messes' (Ackoff, 1979), 'swampy' (Schon, 1987), 'wicked' (Rittel, 1972), and 'turbulent' (Emery & Trist, 1965), where factors change rapidly and unpredictably. Radford (1978) suggested that OR does not take into account these turbulent factors, as approaches like optimization are—for the benefits of a single participant in a static environment—developed for situations that are relatively well understood with reliable data on the characteristics of the situation and for situations much less complex than managers are dealing with. Moreover, OR was perceived to be unable to answer these problems of increasing importance to senior management, so it was relegated down the organisational chain to deal with tactical problems (Eilon, 1977). For example, in organisational planning, OR lost its pre-eminent status due its misunderstandings of the multidimensional aspects of corporate planning (Harris, 1978). At the time, OR was being challenged with new types of social problems that many felt it was ill-equipped to answer; ignoring these problems threatened to stagnate OR, forcing abandonment of a much-needed decision making aid (Dando & Sharp, 1978). This led to the perception or realisation from some practitioners and academics that OR as researched and taught within universities had a number of limitations.

These limitations were outlined by McClelland (1975), who argues that the five assumptions made by quantitative OR imply that it is often not useful for managers. First, OR assumes that systems are discrete and operate in isolation, when in reality systems are interrelated. Second, OR assumes that the information available to managers and OR analysts is not contaminated when in reality it is; OR hides and occasionally amplifies these contaminations. Third, assumptions regarding managerial and organisational objectives have to be made, but these are rarely precise or simple or unitary. Fourth, traditional OR assumes that it is possible to represent the full range of alternatives open to managers; however, this is rarely the case as the mere construction of a model often eliminates certain alternatives. Fifth, OR assumes that outputs can be implemented; in reality, there may not be any political willpower to make the case for change and push changes through. As the types of problems OR was expected to address changed to the social/political problems outlined above, these assumptions started to disintegrate and certain practitioners and academics began to lose confidence in the existing OR approaches on offer.

The seriousness of this shift in perception of OR is highlighted by the action taken by the Operational Research Society in the UK, which commissioned a report on the future practice of OR: "The Commission was established out of a widespread apprehension of an impending, or even an actual, crisis confronting operational research. The focus of its investigation was Britain, and in particular the ways in which the Operational Research Society could most usefully respond to the situation." (Operational Research Society, 1986 p.831).

2.1.3 New type of OR approach

As a result of the perceived crisis, there was a growing movement of people who wanted to address these identified shortcomings in OR and define ways to address or manage these social problems. This challenge was neatly summarised in a widely cited analogy by Schon (1983 p.42) "In the varied topography of professional practice, there is a high, hard ground where practitioners can make effective use of research-based theory and technique, and there is a swampy lowland where situations are confusing 'messes' incapable of technical solution. The difficulty is that the problems of the high ground, however great their technical interest, are often relatively unimportant to clients or to the larger society, while in the swamp are the problems of greatest human concern. Shall the practitioner stay on the high, hard ground where he can practice rigorously, as he understands rigor, but where he is constrained to deal with problems of relatively little social importance? Or shall he descend to the swamp where he can engage the most important and challenging problems if he is willing to forsake technical rigor?". This groundswell of opinion led to some people rejecting the early definitions and underpinning positivistic assumptions of OR based on the quantitative 'scientific method' such as that of Goodeve (1948).

Dando & Bennett (1981) ask if the questioning and subsequent rejection of the 'scientific method' base on purely quantitative models by some constituted a

Kuhnian revolution. A Kuhnian revolution is where the dominant philosophical paradigm is rejected in favour of a new paradigm with more explanatory power of phenomena within the world (Kuhn, 1962). While Dando & Bennett do not make such a claim at a philosophical level, they suggest that a fundamental assumption of OR was challenged and could play out in a similar fashion to the rejection of a Kuhnian paradigm revolution. They argue that by using quantitative methods to solve problems, "O.R. has traditionally proceeded on the assumption that a particular set of answers could be given to such questions? Perhaps not definitively but at least with sufficient confidence to allow work to go ahead in practice with few qualms. For a significant part of the community, this no longer seems to be the case: hence the 'crisis'." (Dando & Bennett, 1981 p.99). This call was echoed by Schon (1995), who asked if OR needed a new epistemology to understand the new types of problems.

In response to their own rejection of quantitative approaches, several scholars proposed and developed new ways of thinking about problems. Once such early proposal in the US was from Russell Ackoff. Ackoff (1979a, 1979b) suggested two ages of thinking about problems, the 'machine age' and the 'systems age'. In machine-age thinking, for a person to understand something they should employ reductionism where they take that thing apart and seek understanding of its constituent parts; this is aligned with the quantitative approaches of traditional OR. This assumes a deterministic concept of the universe where cause and effect relationships can be understood and relied upon to remain true. However, Ackoff (1979b) suggests fundamental flaws with this way of thinking and questions it as an appropriate lens by which to view the world. First, "if we can only understand something by understanding its parts, and if we can only understand its parts by taking them apart, how can we gain ultimate or complete understanding of anything?" (p.95). Second, we must realize the systems being studied are wholes which lose their essential properties when taken apart; therefore, the wholes cannot be understood by this type of analysis. To rectify failings of the machine age, Ackoff proposed moving to the systems age, this is aligned to the rejection of quantitative OR. Ackoff (1979b p.96) described three steps involved in systems age thinking. “First, a thing to be understood is conceptualized as a part of one or more larger wholes, not as a whole to be taken apart. Then understanding of the larger containing system is sought. Finally, the system to be understood is explained in terms of its role or function in the containing system.” Here, we see Ackoff advocating a move away from the quantitative techniques that assume objectivity and optimality and saying that these assumptions do not reflect reality, and that it is not productive to seek an optimal solution to a mess (Ackoff, 1977). Instead, Ackoff argued that OR should pursue systems thinking techniques to examine the planning and design of systems.

In the UK, the research community pursuing such ideas was larger than that in the US; several practitioners and academics took up the challenge of developing OR approaches to try and help with the pressing social problems that quantitative OR struggled to manage. Rosenhead (1989) edited ‘Rational Analysis for a Problematic World’ as the first book to collate these approaches. The book brought together five qualitative approaches: strategic options development analysis (SODA) (Eden & Ackermann, 1998; Eden & Sims, 1979); soft systems methodology (SSM) (Checkland & Scholes, 1990); strategic choice approach (SCA) (Friend & Hickling, 1987); robustness analysis (Rosenhead, 1978) and drama theory (Bryant, 1997). The developers of each of these approaches each contributed two chapters to the book, one focusing on the theoretical underpinnings and development of their approach and the second an example of the approach in practice. The approaches were collectively known as problem structuring methods (PSMs); they were developed independently from each other beginning in the 1960s and were in their early form from the 1980s onwards (Mingers & Rosenhead, 2004). The grouping together of these approaches has not been questioned by OR academics, which suggests that there is acceptance that they warrant a typological grouping. However, because of the reactive development context seen in PSMs, the extent to which they share common philosophical, theoretical, and methodological assumptions has not been established.

The development of OR could be characterised as opportunistic; this is true for the initial development of quantitative OR in the 1930s, with pioneers using their knowledge of mathematics and physics to help with problems such as the placement of radar across the coast of Britain, as described by Williams (1968). It is also true for qualitative OR, where a focus on new types of problems opened the door for new methodologies to make progress with these problems. PSMs allowed a new type of analysis in a context where pervious certainties were becoming the exception rather than the rule (Rosenhead, 2006). However, the difference between the development context of quantitative OR and PSMs was that the quantitative approaches all aspired to conform to a common set of philosophical, theoretical, and methodological rules. For OR to be accepted by War planning decision makers, it needed to conform to the existing paradigm of decision making described as the ‘scientific method’. The positivistic philosophy was held as the standard for research and scientific enquiry, and only approaches that conformed to these set of ideals would be accepted as useful for the basis of decisions. By the 1960s, the search for alternative problem solving approaches lead to the development of the methodologies we now call PSMs. Individual developers (for example, Checkland, Eden, and Friend) were each responding to a specific need they had identified through their own practical experience. For example, in his account of the development of ‘Soft Systems Thinking’, Checkland (1981) describes how the development of hard systems thinking into soft systems thinking was implemented through the application and modification of existing hard system techniques to 'soft' problems. "The course followed was not a theoretical pathway but the result of a particular set of experiences in actual problem situations" (p.150). As each developer responded to their own 'particular set of experiences', they carved and formed the basis for the established PSMs contained in 'Rational Analysis for a Problematic World' (Rosenhead, 1989b). This approach to development across PSMs does not present a case of development based on shared philosophical assumptions, but a siloed approach to research where each developer identifies their own assumptions regarding the underpinning philosophy of their approach. For example, Checkland & Scholes (1999) describe the human activity system as the basis of the system for SSM, while Eden & Ackermann (2004a) describe how SODA is based on personal construct theory. The gap in knowledge that the philosophical differences of these approaches were not considered during the development of PSMs is explored in this thesis.

2.2 A framework to assess the features of problem structuring methods

In 2006, Westcombe, Franco, & Shaw (2006) reviewed the state of PSMs and concluded that the field was stalling, and the lack of new approaches and research across PSMs was stifling innovation in PSMs. According to them, this was compounded by the retirement of the PSM 'gurus' who pioneered PSMs and first developed the main approaches. The authors called for a 'grassroots revolution' from the "community which takes an active role in developing the theory and applications of problem structuring" (p.776). One aspect of this revolution should be the development of new PSMs and, as identified in Chapter 1, (after the period considered by Westcombe et al., 2006) several new approaches have been developed since 2000. As there is still no agreed framework or definition for PSMs, acceptance of new approaches into the established field could be inhibited. The renewed focus on development of new fringe PSMs reignites the need for clarity over what is and is not considered a PSM; this makes the central aim of this thesis timely and pertinent.

The literature has attempted to describe and categorise PSMs in different ways. First, authors have focused on the types of problems that PSMs typically address. Second, authors have focused on how PSMs 'solve' these problems. Despite their age and common grouping, there is no clarity regarding what features must be present for an approach to be considered a PSM. Without this understanding, it is difficult to understand the philosophy, theory, and methodology of PSMs. There is no clear framework for what characteristics need to be present in an approach to warrant it being regarded as a PSM. The current classifications appear to be based primarily on historical conventions. This presents a challenge to the classification of fringe PSMs and the development of existing PSM methodology, as without known parameters, the PSM family may be weakened by approaches/additions that do not share core features. This section presents a framework to delineate PSMs from traditional OR approaches. The acceptance and use of this framework could lead to expansion of PSMs within explicit, rigorous, and known parameters, thereby encouraging new theoretical developments and contributions in the field. The framework developed in this chapter assumes that PSMs make different philosophical assumptions related to traditional OR; thus, it examines the ontological, epistemological, axiological, and methodological assumptions an approach makes by identifying 15 questions to determine if an approach is a PSM. The effectiveness of the framework is tested by applying it to eight OR approaches to see if it successfully delineates PSMs from non-PSMs. The aim of this test is not to show if the established OR approaches are or are not PSMs but to test the framework's effectiveness using known approaches.

2.2.1 Introduction to framework

PSMs are qualitative approaches for making progress with ill-structured problems (Rosenhead & Mingers, 2001b) and sit within OR, but represent an alternative paradigm for problem solving distinct from 'traditional quantitative OR' (Rosenhead & Mingers, 2001b). It has been 40 years since PSMs emerged (Kirby, 2000), but there is still no agreed definition nor qualifying features of what is and is not a PSM.

As Ackermann (2012 p.656) writes, "whilst it is believed that they [PSMs] have similar characteristics and aim to support a particular type of problem there is no agreement as to which methods do and do not comply". The absence of a definition could be a result of the original development context from which PSMs emerged. PSMs were developed in relative isolation with researchers concerned with developing the theory and methodology of their own approach and not concerned with forming a generic theory of PSM. While the theory of individual PSMs was advanced through thorough development, the universal theory of PSM methodology has been more stagnant (Westcombe *et al*., 2006). As evidence for this, Westcombe *et al*., (2006) comment on the lack of new approaches integrated into the literature base, with most authors still relying heavily on the same basic methods proposed by the originators almost 30 years earlier. Now, the second and third generation research community must decide where to focus their efforts. They can choose the isolated strategy of siloed research into individual PSMs, or research that looks across PSMs to help strengthen the field. The second research strategy identifying and developing the theory and methodology of PSMs would pave the way for acceptance and integration of new qualitative OR approaches as PSMs, which may help to energise the field.

Recognising this, Eden & Ackermann (2006) call for development of evaluation frameworks (Midgley *et al*., 2013) and research across PSMs (i.e. how different methods can be adapted and learn from each other), but this has been sparse with recent publications focusing on mixing PSMs together or mixing PSMs with traditional OR approaches (Kotiadis & Mingers, 2006). An agreed definition of PSMs is fundamental to the advancement of PSM methodology. A definition should be available to allow researchers to assess the legitimacy of the new wave of approaches which claim to be PSMs, for example, e.g. visioning choices (O'Brien & Meadows, 2006), morphological analysis (Ritchey, 2006), WASAN (Shaw & Blundell, 2010), DPSIR (Bell, 2012; Gregory *et al*., 2013), issues mapping (Cronin *et al*., 2013) and Wuli–Shili–Renli (Li & Zhu, 2014). A framework could show if the fringe PSM has all the common attributes present in the existing PSMs and therefore ensure that there is no dilution of the field. Thus, this section develops and tests a framework of criteria to define what is a PSM. The framework will broaden the understanding of PSMs and the theory of PSMs by identifying key features present in all PSMs. Once the framework is established and tested, it can be used to assess the veracity of the claim made by fringe PSM methods. It may not matter for established OR and non-OR approaches, but the classification of new approaches does matter. Accepting approaches which do not share the same common features as PSMs and therefore cannot contribute to the theory of PSMs may compromise the identity of PSMs, thereby rendering the term meaningless. Thus, the framework is applied to PSMs and non-PSMs to assess its capability to differentiate between OR approaches.

Underpinning the framework developed in this thesis is the view that (compared to other problem solving methods) PSMs make unique assumptions regarding the nature of problems and how we can solve them (Rosenhead & Mingers, 2001b). Furthermore, PSMs are underpinned by a paradigm: a framework of ideas (Checkland & Holwell, 1998) which need to be satisfied if an approach is to be regarded as a PSM. To specify this framework, this thesis takes insights from

Guba & Lincoln (1994 p.108, 2005), who define the following assumptions of the paradigm:

- ontology, the form and nature of reality and what can be known;
- epistemology, the nature of relationships between the knower and what can be known;
- axiology, what is valued in terms of research process for generating knowledge;
- methodology, how the knower can find out what can be known.

We use these concepts to build the framework.

2.2.2 Defining PSMs

In defining PSMs, the thesis recognises that some of the literature cited while building the framework predates the emergence of PSMs (in some cases by decades). However, these sources set the foundations for the development of future research in OR, which have been addressed by PSMs over time. The features these sources illustrate were integrated by PSM developers into their approaches; these features are still prevalent in PSMs today. Therefore, including these sources is critical to understanding and defining PSMs and the framework is richer for it. For ease of reading, this work is cited as if it were referring directly to PSMs.

Reviewing the literature base revealed that when authors are describing PSMs, they do so using combinations of three different criteria. Authors differentiate PSMs from traditional OR by focusing on characteristics of the problem, how PSMs analyse problems, and philosophical dimensions. First, definitions focus on the characteristics of the problems PSMs are employed to address. These types of problems have been called 'messy' (Ackoff, 1979), 'swampy' (Schon, 1987) and 'wicked' (Rittel, 1972); these labels indicate that such problems have little order to them and are not easily 'solvable'. Describing the characteristics of these problems, authors have said that they are pluralistic (Jackson & Keys, 1984) as stakeholders have divergent views about goals/objectives. The problems exist in dynamic and complex systems that interact with each other (Ackoff, 1979b). While these problems are varied and it is difficult to exhaustively list their attributes, Churchman (1967) regards them to share many of the following properties: they cannot be exhaustively formulated, every formulation is a statement of a solution, there is no stopping rule, no true or false, no exhaustive list of operations, many explanations for the same problem, every problem is a symptom of another problem, there is no immediate or ultimate test; solutions are 'one shot', and every problem is unique. Other authors add that problems often lack reliable data (Mingers & Brocklesby, 1997) and standard mathematical techniques are not applicable (Simpson, 1978), as problems are defined by a social construction by actors (Keys, 2006) and require constant negotiation (Pidd, 2009). Given their diversity of form and interpretation, the problems rarely fit neatly into rigid analytical frameworks (Checkland, 1983). Writing about the crisis in OR, Sadler (1978 p.6) note how in a post-industrial society, the problems being tackled by major organisations are changing and no longer solely focus on efficiency: "problems in the real world are 'messy wholes'. They have their quantitative and qualitative aspects, their logical and irrational components, their technical, economic and social dimensions. OR practitioners must be prepared to solve problems, not just those aspects of problems capable of mathematical resolution. To do so, calls not only for a new armoury of techniques, but a whole new approach to education and training." Therefore, PSMs do not merely address a different type of problem but were developed to address a new type of problem as the existing set of approaches could not manage these problems. These messy problems are diametrically opposed in their formulation to the rigid, more ordered problems of the past and therefore require a new type of problem solving approach. This is referred to as the 'moon-ghetto metaphor', that is, the (false) assumption that the same problem solving methods utilised to get humans to the moon could be used to solve problems associated with inner-city ghettos (Nelson, 1974). This was actually shown when the RAND Corporation attempted to apply the cause and effect modelling approaches, which had proven useful in aerospace problems, to the issued present in city governments. When RAND used these tools and methods in public health administration, they encountered comprehensive failure (Greenberger, Crenson, & Crissey, 1976).

Second, definitions focus on how PSMs analyse a problem. PSMs build models of situations (Franco, 2013), where a model is a representation of a situation that supports negotiation, or develops new understanding. The models are qualitative (Ackermann, 2012) often representing data from differing worldviews (Mingers, 2011). PSMs reject reductionism (Ackoff, 1979b) where individual elements are optimised independently of the whole. Instead, they manage complexity (Rosenhead, 2006) by adopting a holistic approach, seeing problems as systems where elements are connected by interrelationships rather than static snapshots (Senge, 1990). Thus, PSMs explore systemic issues (Midgley *et al.*, 2013) and discover emergent system properties (Checkland, 1981). They aim to build shared understanding and commitment across stakeholders (Eden, 1995) through facilitation (Franco & Montibeller, 2010), participation (Rosenhead, 1996), and stimulating dialogue (Mingers & White, 2010) through a structured decomposition of issues. Rather than relying on the analysis of abstract data (Mingers, 2000), a social process of learning occurs through which actions are agreed upon (Pidd, 2009).

Finally, philosophical definitions centre on PSMs differing from ‘traditional OR’ on the assumptions made regarding the nature of problems. As mentioned in the introduction to this chapter, traditional OR assumes reality can be objectively modelled, thereby implying that there are well-specified/agreed upon objectives; thus, the analyst has to determine an efficient means of realising these objectives

(Checkland, 1978). In response to the crisis in OR, PSMs adopt interpretivist and social constructivist views that situations are constructed differently by people and, thus, are subjective and require participation (Gregory, Atkins, Burdon, & Elliott, 2013).

These three classes of definition have been useful to describe PSMs and provide a general context in the beginning of journal papers. What they do not provide is a sufficiently detailed classification against which fringe PSM can be assessed; they do not provide the basis for expansion of the theory of PSMs, and they do not provide prospective methodology developers clear parameters by which to think about how they might approach a new problem if they wanted to develop their own PSM. To assess what is a PSM requires a comprehensive framework encompassing a breadth of characteristics and providing a structure against which any approach can be tested. This project begins the process of building this framework by identifying four pillars that underpin the original PSMs and providing specificity to these pillars by identifying specific features which are present in PSMs.

2.3 The four pillars of PSMs

The four pillars of PSMs were identified from a comprehensive literature review which was mapped onto the philosophical framework by Guba and Lincoln, the constructs from which were operationalised for OR by Mingers (2003) [Table 2]. The first construct, ontology, guides users on the types of problems to which an approach can be applied, aspects to model, and general system characteristics required to apply an approach. Thus, we can identify the ontological assumptions made by an approach by understanding what elements are included within models that are built using that approach. This identifies Pillar 1—the characteristic and scope of the system modelled by the PSM, called ‘systems characteristics’. This research project identifies the other three pillars before discussing them.

Mingers (2003) operationalised epistemology as how knowledge is created using an approach, by whom, and identifying goals of this knowledge creation. Thus, the epistemology of an approach can be identified by understanding how knowledge is created and if the model is believed to represent an objective reality or a social construction of the individuals involved in the model building process. Therefore, Pillar 2 defines the 'knowledge and involvement of stakeholders' to ensure that the required breadth/depth of insight is available. Mingers operationalised axiology as judging the value of the intervention and the insight it produces. Thus, the axiological assumptions made by an approach can be identified by considering how an approach values what 'good research' is. Therefore, Pillar 3 represents the 'values of model building' through the contribution of model building to the discovery of new knowledge. Mingers published his paper in 2003, but in 2005, Guba and Lincoln added the theoretical construct 'methodology'. Here, methodology is operationalised as the structured process of analysis and modelling that an approach adopts to formally build and represent knowledge. Thus, the methodological assumptions made by an approach can be identified by the structure through which the approach builds knowledge about the problem. Therefore, Pillar 4 represents the 'structured analysis' of knowledge using formalised rules and its representation in models.

The next stage is to review the PSM literature to provide depth to the framework by identifying a range of characteristics that must be identified before an approach can be considered a PSM. Each characteristic is aligned to a pillar and specifies a question that, when asked of an approach, uncovers if the PSM feature is present, thereby aiming to deduce whether the approach is a PSM. These questions are numbered and shown in italics throughout this section. These questions, and therefore the framework, are subsequently tested in this project by seeing if it can successfully determine whether a range of well-established OR approaches are PSM. For an approach to be considered a PSM, it should answer yes to all 15 questions in the framework.

Theoretical Construct	Theoretical meaning (Guba and Lincoln)	Operationalised construct (Mingers)	The pillars of PSMs
Ontology	What is assumed to exist	What is included within a model	System Characteristics
Epistemology	The nature of knowledge	How and with whom is knowledge created	Knowledge and Involvement of Stakeholders
Axiology	Values for problem solving	How to judge the value of PSM research	Values of Model Building
Research Methodology	How to structure enquiry		Structured Analysis

Table 2 Theoretical construction of the four pillars

2.3.1 Pillar 1: Systems characteristics

OR approaches build models which reflect a system of elements that interact with each other. What is included within the model depends on both the problem context being modelled and the approach used to model it. The same context modelled using different approaches will produce different models, just like a photo, x-ray, and ultrasound of the same person's abdomen will each show different properties of that abdomen and may lead a medical doctor to arrive at different conclusions about a patient's condition. In OR, analysts choose which elements to include and exclude from a model based on the approach they are using. The elements chosen to be represented in a model reflect the ontological assumptions of the approach. This is both in terms of the types of elements modelled (feedback loops, human activity systems etc.) and the boundary of the model (the scope of the modelling activity).

Thus, the first characteristic considered is how the system being analysed is conceptually separated from its environment by a systems boundary (von Bertalanffy, 1956). Within the boundary is the 'system domain' and outside is the ‘environment’ (Yolles, 1999). von Bertalanffy specified two type of system boundaries—open and closed. “A closed system engages in no exchanges with its environment. An open system, such as an organism, has to interact with its environment to maintain itself in existence. Open systems take inputs from their environments, transform them and then return them as some sort of product back to the environment.” (Jackson, 2003 p.6). To understand which of these boundary types are used in PSMs, the framework looks to Checkland's (1981 p.312) definition of a system boundary to see if it is open or closed. For Checkland, a system boundary is “… the area within which the decision taking process of the system has power to make things happen, or prevent them from happening”. This is in keeping with the notion of an open system. The boundary described by Checkland does not isolate the system from its environment ensuring the system in equilibrium. Elements that were not originally within the system boundary are able to enter and influence the system, and elements that were within the boundary at the beginning can leave the system. There are known and unknown elements external to the boundary that are not within the control of model users; therefore, a PSM boundary typically represents what can be influenced or reacted to. What is within the boundary can also be effected by elements external to the boundary; thus, the open boundary is permeable. This aspect leads to our first question: *Does the approach draw an open boundary around the system?*

Second is whether or how to model systems at different hierarchical levels. Systems modelled are usually part of a wider meta-system. For example an Operational Research Group, may be part of a wider Business School which is comprised of several other academic groups. The Business School itself is also one school from a wider University, which itself will have other schools of study. Each vertical step up represents a new management structure which has several operational sub-units to manage. At the Business School level, the OR group represents one of the multiple sub-units. Modelling these hierarchical systems presents conceptual and practical challenges for modellers. To help conceptualise this, modellers can use the concept of recursion which describes how every system contains and is contained within a system (Beer, 1981). Recursion deals with the 'architecture of complex organisations' and the idea that systems comprise a series of sub-systems that are autonomous, adaptable, self-regulatory, and self-organising (Watts, 2009). When modelling, it can be helpful to assume one system in focus at a single vertical level of recursion if relevant modellers can consider the relationship between the system in focus and the levels of recursion immediately above or below the system in focus (Leonard, 1999). Despite this simplifying assumption, there is still a recognition that the modelled system does not exist in isolation from a wider hierarchy. Much like how the open system boundary acknowledges wider elements of a system that can be controlled by the decision maker, a system hierarchy represents the presence of systems with higher or lower authority than the one in focus. Question 2: *Does the approach acknowledge there are systems at different hierarchical levels to the one being modelled?*

Another aspect is how the approach models complexity within a system. Ackermann (2012) states that PSMs focus on managing (rather than reducing) complexity, examining the whole picture, and not breaking problems into constituent parts. This enables decision makers to understand the emergent properties of the system (Checkland, 1981). Emergent properties are those which are present in complex phenomena but cannot be explained from the characteristics of their isolated parts (von Bertalanffy, 1968). Traditional OR approaches adopt a more mechanistic view which assumes that phenomena are predictable and inherently understandable (Jackson & Keys, 1984). The mechanistic view leads to reductionism (Ackoff, 1979b), where cause and effect relationships are measured assuming that knowledge of all these individual relationships would lead to knowledge of the entire system. The notion of reductionism as a way to derive learning and knowledge about a system was challenged during the crisis in OR "because of the complexity and unbounded character of real-world problems and because of the interactive nature of their parts" (Jackson, 2003 p.61). The emergent properties of systems do not exist when systems are decoupled into smaller parts (Rubenstein-Montano et al., 2001), so using this approach does not enable learning about the entire system. Reducing complexity by breaking a system apart does not lead to sufficient understanding of the system, so we must adopt an alternative approach, managing complexity and maintaining the emergent properties. Question 3: *Does the modelling approach seek to manage complexity?*

All analytical modelling approaches use a modelling language "employing concepts such as system, subsystem, hierarchy, boundary and control" (Jackson, 2003). Each approach has some elements that are used in the modelling language that is unique to that approach. For example, SSM investigates human activity systems (Checkland & Scholes, 1990) and SODA analyses causal relationships of strategic matters (Eden & Ackermann, 2001). Moreover, PSMs should be clear on the modelling language used to ensure that all modellers using that approach share a common lexicon. The modelling language will guide what is being modelled and how to represent the elements of the system. Question 4: *Does the approach model an identifiable system?*

2.3.2 Pillar 2: Knowledge and involvement of stakeholders

OR techniques use models to construct and represent knowledge about an area of concern. It is generally accepted knowledge about the system in focus will be is created through analysis of the model representing that system however, knowledge is also generated through the process of data collection and interaction with the system and its people. The manner in which knowledge is created and who gains that knowledge reflects the epistemological assumptions of the approach.

Knowledge creation is aided by the representations of a problem situation in a model. The form the model takes affects the knowledge creation process. PSM models take a qualitative form and are thus often diagrammatic (Ackermann, 2012) and represent differing perspectives. This was in response to criticisms during the crisis in OR for modellers to understand more about the situation being modelled. There was a perceived need for OR models to incorporate aspects of behavioural theory qualitative data to be able to ask questions such as 'what we do?', 'want to do?', 'ought to do?', instead of just 'what can we do?' (Harris, 1978). This is in contrast to the quantitative representations of reality that typify traditional OR models and represent a more objective standpoint. Question 5: *Does the approach build a qualitative model?*

The next characteristic is the process of eliciting knowledge to build a PSM model. Franco & Montibeller (2010) argue that building a model can be done in two modes, expert and facilitator. In expert mode, the problem situation faced by a client is given to the OR analyst who builds a model to develop a (quasi-)optimal solution. In facilitator mode, the consultant jointly develops a model through participant interaction possibly in a group workshop. Checkland & Scholes (1990) add the facilitated approach which can be split into two modes. The traditional facilitated approach is called Mode 1, where there is a formal group level application. In Mode 2, an approach is applied by an individual to structure their own thinking. Mode 1 enables participants to change their views by learning from others about the problem situation. Facilitated approaches are consistent with PSMs, where a facilitator brings process knowledge to model the clients' context knowledge (Phillips & Phillips, 1993). The model becomes the focus for negotiation (Fisher & Ury, 1999) by driving the process of negotiation towards agreement (Eden & Ackermann, 2006), with the model acting as a transitional object (Eden & Sims, 1979). Question 6: *Can the approach build a model in a facilitated way?*

For PSMs, stakeholder learning is critical (Checkland, 1985a). PSMs do not seek to mechanically design a solution as much as orchestrate a process of learning about the problem situation (Khisty, 1995). Through learning and negotiation, there can be a degree of agreement about the nature of the problem among parties involved, which leads to action (Mingers, 2011). Learning arises from participants sharing situational knowledge to build joint definitions and construct problem resolutions within a model. A shared model helps stakeholders to identify how their knowledge inter-relates (Ackermann, 2012); this leads others to acquire knowledge from what has been shared and create knowledge by synthesising competing views (Edwards et al., 2009). The learning from PSM workshops aims for divergent worldviews to become more closely aligned (Pattison, 1995). Question 7: *Does the approach focus on participants learning about the problem?*

Finally in pillar 2, PSMs prioritise taking actions that are systemically desirable and culturally feasible (Ormerod, 1996a). PSMs assume that it is better to have a good set of actions that improve the situation, are politically feasible, and can be implemented (Checkland, 1981). Some other OR approaches seek optimal solutions, but during the crisis in OR many authors refuted the value of seeking optimal solutions. First, as Ackoff (1979b p.7) states, the "optimal solution of a model is not an optimal solution of a problem unless the model is a perfect representation of the problem, which it never is." Second, optimal solutions may never be implemented if political factors do not also inform the model. Therefore, building knowledge about the optimality of a situation is not the aim of PSMs; instead, PSMs focus on learning and political feasibility. Political feasibility can be gained through recognition of power structures, getting buy-in from important stakeholders (Eden, 1992) and participation in the process. Stakeholders can explore perceptions of the problem and find agreement/accommodation between participants' conflicting constructions (Checkland, 1985b). Participation goes beyond merely consulting stakeholders by enveloping multiple stakeholders in model building (Davis et al., 2010). Participation aims to increase commitment for implementation as key stakeholders perceive their views and inform the analysis, and the model reflects solutions that they jointly develop (Franco & Montibeller, 2010). Question 8: *Does the approach aim to produce politically and culturally feasible solution over optimal solutions?*

2.3.3 Pillar 3: The values of model building

An OR approach must have a set of values by which to judge the quality of analysis. These values will reflect the axiological assumptions of that approach. Guba & Lincoln (1989) introduce four criteria for judging the quality and rigour of qualitative research: credibility, transferability, dependability, and confirmability. These criteria were used by Shaw (2006) to judge the value of journey making workshops (similar to SODA). Shaw showed their compatibility with PSMs, so we turn these values into questions for the framework.

Credibility requires the data to accurately reflect stakeholders' social constructions. PSMs recognise that problems are multi-perspective, allow a range of distinctive views to be explored, and embrace conflicting objectives without collapsing them into a single function (Mingers, 2011). Instead of trying to define a 'real' problem the focus is on agreeing a joint problem definition which encompasses the main features of individual perceptions (Franco & Montibeller, 2010). Question 9: *Does the model reflect the different social realities of the participants?*

Transferability is the extent to which methodological findings can be generalised and used in other problem contexts. The model building approach should be suitably generic that it is not limited to a single setting but can be used with a diverse set of problems and clients. This was one of the main reasons the claim in Shaw & Blundell (2010) that WASAN was a PSM was rejected by the EJOR reviewers when the manuscript was first submitted. Mingers & Rosenhead's (2004) review of PSMs identified many practical examples of PSMs used in different problem contexts. For example, mining (Pauley & Ormerod, 1998), Health Care (T. Hindle, Checkland, Mumford, & Worthington, 1995; Wells, 1995), Transport Planning (Khisty, 1995), designing briefing systems (Bennett, 1994), and information systems development (Ormerod, 1996b). Question 10: *Is the model building process suitably generic so it can be transferred to multiple problem contexts?*

On dependability, traditional OR methods attempt to show that outputs are reliable by demonstrating their economic (substantive) rationality, that is, when outputs are appropriate to achieve stated goals within the limits imposed by given constraints (Simon, 1976). PSMs are used in situations where a single goal and explicitly stated constraints may not exist as these factors are constructions of different stakeholders and so will vary depending on whose perspective is being considered. Therefore, in addition to showing that outcomes are substantively rational, PSMs need to show reliability in outcomes by showing that a logical procedure has been followed. In part, dependability puts focus on the process of collecting data (Shaw, 2006). This is called procedural rationality, which is when "the procedure itself is the outcome of a publically stated reasoning and so can gather cognitive commitment from participants" (Eden & Ackermann, 1998 p.55). To show that the outcomes are dependable, procedures that are considered legitimate by the group are followed (Ackermann, Andersen, Eden, & Richardson, 2011). Question 11: *Does the approach rely on showing procedural rationality to give reliability to outcomes?*

Confirmability requires that the data in a PSM model is firmly grounded in the situation being studied and not the facilitator's own constructions. Furthermore, confirmability suggests that the outcomes are grounded in the content of that model and are traceable to its source—that is, that a validated audit trail of stakeholder views exists, leading to model content, leading to outcomes. This is different from the definition of validation applied to traditional OR by Finlay & Wilson (1987 p.304) where “Model validation tests the agreement between behaviour of the model and the real world system being modelled.”. Confirmability focuses on ensuring a transparent path of inferring findings. Question 12: *Does the model build a validated audit trail of the decision making process?*

2.3.4 Pillar 4: Structured analysis

OR approaches have structured processes to build/analyse a model to create knowledge. The manner in which an approach is deployed will alter the types of knowledge that is built. There is commonality among PSMs in how they structure an intervention; therefore, these common features can be included within the framework.

PSMs have the higher-order status of a methodology. A method is a technique that leads to a specific output, for example, developing a root definition (Mingers, 2011). There is no agreed definition for methodology within the PSM literature, although Checkland (1981) and Jackson (2006) define methodology as the interface between philosophy and method. If philosophy provides broad guidance on ‘what’ should be achieved and method gives specific guidance on ‘how’ to do something, then methodology contains elements of both ‘what’ and ‘how’. Thus, methodology should translate theory into practice and is concerned with the principles of method use. Mingers (2011) defines methodology as involving several different methods; in this sense, SSM and Journey Making would both be methodologies. We use Mingers’ definition for methodology to build this framework and assume that all approaches (method or methodology) have a basis in philosophy and translate theory into practice expressing their philosophical basis through four pillars. Mingers' definition also highlights the area of importance, building knowledge through different stages allows different phases of analysis, which should be critical to the success of a PSM intervention. For the purposes of the framework, this thesis take Mingers definition of methodology into account in this question; however, the thesis does not reject the definitions of methodology from Checkland (1981), Jackson (2006), or Guba & Lincoln (2005). Question 13: *Does the approach structure knowledge through different stages of analyses i.e. is it a methodology?*

The different stages of analysis in PSMs allow for different types of thinking, PSMs incorporate stages of both divergent and convergent thinking. Separating these two phases of thinking can increase group performance (Shaw, 2003). During divergent thinking, participants are encouraged to think with richness and variety to increase the likelihood of identifying creative solutions (Franco & Montibeller, 2010); evaluating alternatives (and therefore potentially rejecting or accepting them) too early is discouraged (Ackermann, 1996) as this will limit willingness to look further or think more creatively. Convergent thinking allows participants to identify commonalities in views (Franco & Lord, 2011) and consolidate the best ideas in preparation for the next stage (Franco & Montibeller, 2010)—the temptation to revert to divergent thinking is discouraged (Ellspermann, Evans, & Basadur, 2007). Phillips & Phillips (1993) cite many poor practice examples where groups converge and reject ideas before they are fully explored. Question 14: *Are there distinct phases for divergent and convergent thinking?*

PSMs adopt a staged approach to knowledge creation, with new knowledge created in each stage. At the conclusion of each stage, knowledge takes its rightful route in being either discarded (e.g. if incorrect), parked (e.g. if irrelevant), translated into later stages of analysis, or used to form final outcomes if it is accurate and relevant. However, this may not always happen; for example, accurate/relevant knowledge can be lost through misrecording, misunderstanding, or miscommunication (type 1 leak), or inaccurate/irrelevant knowledge is carried forward (type 2 leak). We term these 'knowledge leaks' as knowledge that has not followed its rightful route [see Figure 2]. Accurate and relevant knowledge should be used and not lost between stages, and PSMs should maximise knowledge use (and avoid knowledge leaks) by having clear recording and validation processes. To avoid knowledge leaks, the output from a method/stage should be the input to subsequent stages. For example, in SSM, the knowledge from awareness building (Stage 1) informs rich pictures (Stage 2), both of which inform root definitions (Stage 3), and so on. This emphasises that knowledge builds across stages and that analysts can revisit earlier stages if additional knowledge/clarification is needed. This is a new contribution by the researcher, and it was not identified during the literature review but when the researcher was trying to identify if there were gaps in the framework. Question 15: *Does the approach manage knowledge through the methodology to avoid 'Knowledge Leaks'?*

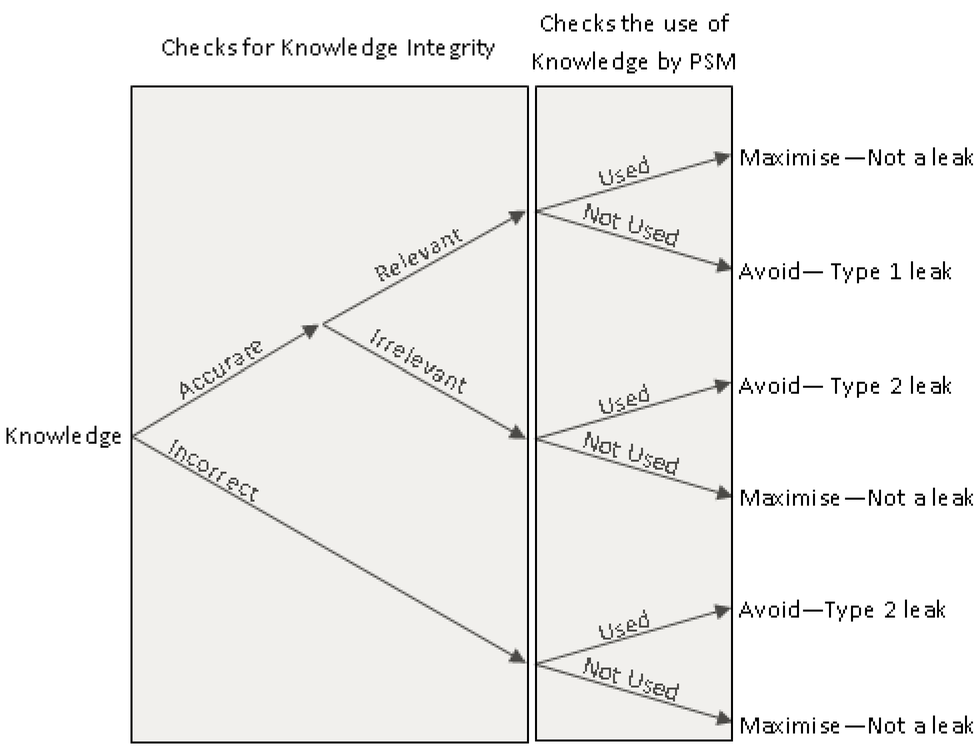

Figure 2 Knowledge leaks

2.4 Testing the four pillars

The above section detailed the four pillar framework, which evaluates whether an approach has the common features of PSMs. This section explores the validity of these 15 questions by evaluating if the framework effectively delineates PSMs from traditional OR methods. To demonstrate breadth and variety of application, eight approaches from across five categories of OR are examined using the framework. Three PSMs are chosen from Rosenhead & Mingers (2001a): Soft Systems Methodology (Checkland, 1981), Strategic Options Development Analysis (Eden & Ackermann, 1998), and Strategic Choice Approach (Friend & Hickling, 2005). One approach is taken from each of the three non-soft OR categories from the OR taxonomy by Williams (2008): From 'methods to calculated an attribute of a system', data envelopment analysis (DEA) (Charnes et al., 1978); from 'methods to replicate or forecast system behaviour', simulation (Robinson, 2004); and from 'optimisation methods', linear programming (LP) (Albright & Winston, 2007). Finally, to assess if the framework can distinguish between PSMs and similar approaches, two approaches classified as being related to PSMs by Mingers & Rosenhead (2001) are chosen: Viable Systems Model (VSM) (Beer, 1981) and System Dynamics (SD) (Forrester, 1961).

The three PSM approaches used to test the adequacy of the framework, were introduced and explained briefly in Section 1.1; however, the five non-PSM approaches were not discussed. Section 2.4 introduces these five approaches. It is assumed that the reader of this is proficient in OR and therefore will already possess a working knowledge of these five approaches. Thus, the descriptions have been kept brief with references provided for the reader to follow up for more information. Following these descriptions is a discussion of each question in relation to the eight approaches, stating whether the approach satisfied the requirement of being a PSM.

Viable Systems Model

The VSM is derived from management cybernetics and describes how sustainable organisations should be configured. It proposes minimum functional criteria through which an organisation can be capable of independent existence and respond to changes in the external environment. VSM states the variety within an organisation (internal variety) must at least match the variety present in its environment (external variety) so the organisation can respond to environmental disruption through 'requisite variety'. Comparing an organisation to this idealised model, the user can diagnose deficiencies in an existing system. VSM specifies that five subsystems are needed in any viable system: S1 Operations, S2 Co-ordination, S3 Control/Monitoring, S4 External Environment, S5 Policy. For further information, see Beer (1981).

System Dynamics

SD uses influence diagrams to represent how stocks flow between elements of a system over time. Influence diagrams model system behaviour through feedback loops which are positive (reinforcing) or negative (balancing). First, a qualitative conceptual model of the system is developed, to which quantifications of relationships are added leading to a quantitative model. SD models can be built in facilitated Mode 1 or non-facilitated Mode 2, and this thesis considers Mode 1 when SD is closer to PSMs, thereby providing a more challenging test of the framework. For further information, see Forrester (1961).

Data Envelopment Analysis

DEA identifies the relative efficiency of decision making units (DMUs) that produce multiple outputs through the use of multiple inputs. The efficiency of a DMU is quantified relative to other DMUs with the restriction that all DMUs are members of a production possibility set and they lie on or below an efficient frontier. DMUs on the frontier are 100% efficient. The efficiency of DMUs below the frontier is quantified relative to a hypothetical DMU sitting on the frontier. For further information, see Charnes et al., (1978).

Simulation

A simulation model is a simplified imitation of a system providing the ability to experiment how it changes through time. Benefits of simulation include the prediction of performance, avoiding disruption of the real system, reducing the risk of system failure, providing performance measures and overviewing performance. Different types of simulation models include discrete event and agent-based simulation and Monte Carlo simulations which reduce risk by running a large number of simulations using random numbers within a probability distribution. The law of large numbers implies that averaging the results of numerous experiments yields a more rigorous approximation of system behaviour. For further information, see Robinson (2004) and Greasley (2004).

Linear programming

LP is a type of optimization model. Decision variables are values chosen by the decision maker, which impact the overall objective. The objective function is a value to be optimised (maximised or minimised) and will be effected by decision variables; constraints are conditions to be satisfied. In addition, LP assumes the following aspects: 1) proportionality, the effect of a decision variable in any one equation proportional to a constant quality; 2) additivity, the sum of the contributions from various activities to a particular constraint equals the total contribution on that constraint; and 3) divisibility, that both integer and non-integer levels of the activities are allowed. For further information, see Albright & Winston (2007).

This section evaluates the effectiveness of the 15 questions in the framework on whether they successfully delineate the eight OR approaches. If the questions are successful, then only SSM, SODA, and SCA should answer yes to all questions. This would show two things: First, the four pillar framework only identifies features that are present in all of the established PSMs. Second, some of the features in the four pillar framework are absent from non-PSMs. This would show that the four pillar framework is useful to discriminate between approaches that do and do not demonstrate the features common to PSMs. Providing answers to some of the 15 questions is unproblematic as answers are clear-cut from the given definitions to the PSMs and non-PSMs or a basic knowledge of the area. In these instances, only once sentence is used to justify an answer. However, some require more than a basic justification; in these instances, references have been provided to justify the answer for each approach. In all cases, the purpose of each paragraph is only to answer the question and therefore offer descriptive accounts which have purposefully been kept short. Summary answers to questions are presented in Figure 3, Figure 4, Figure 5 and Figure 6.

2.4.1 Pillar 1: Systems characteristics

Does the approach draw an open boundary around the system?

SSM builds models of the human activity system, a characteristic of which is the open permeable system boundary (Pidd, 2009) across which communication and interaction occurs. SODA shows how a person or group define an issue and record how issues effect (or are effected by) the external environment, thereby creating an open boundary. SCA draws an open system boundary using a decision graph to map a number of connected issues; a boundary is drawn around a subset of these and will be analysed. An internal/external divide is also used in VSM to recognise the difference between internal and external systems and draw the boundary to show the interactions of the internal system with its environment.

SD, DEA, simulation, and LP draw a boundary around the system that excludes other areas from the analysis. The model of the system isolates external factors, and only the elements within the system boundary have effect on model outputs. These characteristics create equilibrium within the system; nothing enters or is lost to the environment that is external to the modelled system.

Does the approach acknowledge there are systems at different hierarchical levels to the one being modelled?

The recursive system theorem, which is defined in VSM, states that "If a viable system contained a viable system, then the organisational structure must be recursive" (Beer, 1981 p.288). Stated another way, it can be said that in a recursive organisational structure, any viable system contains, and is contained in, a viable system. This creates an explicit hierarchy with vertically recursive higher order systems placed within a hierarchy. Checkland & Scholes (1990) note that SSM is designed to model different hierarchical levels of systems; thus, it is built at a single hierarchical level at one level of recursion. SCA suggests that when evaluating different decision areas, it may be useful to organise them into levels of choice where decisions affecting wider, more general areas are separated from those examining more specific ones (Friend & Hickling, 2005). SODA and DEA can also model hierarchically, but models should only represent a single recursive level. In SD and simulation, models can be built at different hierarchical levels with data from lower-level models feeding into higher-level models.

LP does not consider a hierarchical world of wider systems as all elements must be considered within the model.

Does the modelling approach seek to manage complexity?

SSM, SODA, SCA and VSM all manage the complexity within a system by holding complexity within the model. They codify system properties in a specific form to represent its complexity, not reduce it. This allows decision makers to consider systemic properties. For example, SCA uses the shaping mode to make judgments about the connectedness between one field of choice and another (Friend & Hickling, 2005).

SD, DEA, simulation and LP do not attempt to manage the complexity within a system, but reduce complexity by breaking the system into constituent, related parts. By observing individual relationships in the real world and reconstructing them according to a set of predictable rules, the analyst builds a model that represents the system. However, as the system reduces the complexity, it can only calculate solutions according to these predefined rules and the decision maker may have lost information that would have been useful.

Does the approach model an identifiable system?

All the approaches are clear about the system being modelled. SSM models the 'Human Activity System' (Checkland & Scholes, 1990), the "modelling language used for making models of human activity systems is all the verbs in language; an indicator of logical dependency; indicators of flows, concrete or abstract" (Checkland, 1981 p.315). SODA builds cognitive maps which are designed to represent the way in which a person defines an issue (Eden & Ackermann, 2001). The cognitive map is made up of constructs (nodes) linked to form chains (shown by arrows) of action oriented argumentation (Eden & Ackermann, 1998). SCA builds several models that represent the interconnectedness of decisions with the aim of reducing uncertainty (Friend, 2001). VSM outlines 5 sub-systems that are required for an organisation to remain viable (Beer, 1981). SD draws causal loop diagrams that consist of factors joined by arrows showing the causal links between them. Each arrow is labelled with a '+' or '-' to show how the dependent variable responds to a change in the dependent variable (Sterman, 2000). A DEA model consists of inputs and outputs from a system of DMUs that are used to calculate the relative efficiency of DMUs compared to other DMUs within the system. Simulation models show how an entity moves through a system over time. LP models are built with constraints defining a feasible range, or convex hull. An objective function is either maximised or minimised within this feasible range to provide an optimum answer for the defined system.

Pillar 1: System characteristics								
Q1 Does the approach draw an open boundary around the system? *Q2 Does the approach acknowledge there are systems at different hierarchical levels to the one being modelled?* *Q3 Does the modelling approach seek to manage complexity?* *Q4 Does the approach model an identifiable system?*								
Question	SSM	SODA	SCA	VSM	SD	DEA	Sim*	LP
Q1	Yes	Yes	Yes	Yes	No	No	No	No
Q2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Q3	Yes	Yes	Yes	Yes	No	No	No	No
Q4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* Simulation (Sim) has been abbreviated

Figure 3 Pillar 1: System characteristics summary

2.4.2 Pillar 2: Knowledge and involvement of stakeholders

Does the approach build a qualitative model?

Qualitative models are built in SSM, SODA, SCA, and VSM, while SD builds both quantitative and qualitative models. In SD, the qualitative model shows the interrelationships between different elements of a system by qualitatively mapping the feedback loops between these different elements. Then, quantitative data is collected to show the stocks and flows between the different elements of the system, which is the input for a quantitative model.

DEA, simulation, and LP help to build models that objectively represent the situation using quantitative variables that are interconnected.

Can the approach build a model in a facilitated way?

SSM, as described by Checkland & Scholes (1990), can be used in facilitated Mode 1 as well as in non-facilitated Mode 2. Similarly, VSM, SODA, and SD models can be built in Modes 1 or 2. SCA models are typically built in a Mode 1 fashion.

The selection of input-output variables to build DEA models is usually based on the result of conversations between analysts and experts in the units being assessed, supported by quantitative analysis (Casu, Shaw, & Thanassoulis, 2005), and the model is then built in expert mode. Casu et al. (2005) used journey making (a PSM approach derived from SODA) with a group of stakeholders to determine input-output variables. This facilitated approach constitutes a different data collection technique. However, while the model built with the stakeholders to identify input-output variables was through facilitation, the DEA model was built in expert mode; thus, DEA does not build models in facilitator mode. Simulation and LP models are not usually built in a facilitated manner, although some work has built facilitated simulation models (Robinson, 2001).

Does the approach focus on participants learning about the problem?

Learning arises from participants sharing knowledge with each other, leading to them to acquire and create knowledge by synthesising views (Edwards et al., 2009). SSM does this by encouraging participants to discuss different worldviews during group modelling. SODA enables participants to share knowledge through the building of composite or group causal maps. SCA promotes knowledge sharing and learning through orientation within the A-TOPP framework. The A-TOPP framework represents the four elements technology, organisation, process, and product, each with two opposing orientations. With regard to SCA, Friend & Hickling (2005) suggest that groups should adopt open technology so many can share ideas, allowing participation to be interactive and learning to be enhanced.

VSM, SD, DEA, simulation and LP do not originally focus on participants learning during model building. Their focus for clients is often to learn about potential solutions, so wider learning is not built into their modelling framework by explicitly contributing to the success of a particular application.

Does the approach aim to produce politically and culturally feasible solution over optimal solutions?

To build political feasibility, approaches increase participation through enveloping stakeholders in the process and addressing issues of power within the problem situation; both these elements are considered below. SSM seeks outcomes that are both desirable given the models and culturally feasible for the people involved. Therefore, stakeholders seek accommodations between different worldviews, that is, solutions different stakeholders can 'live with' (Checkland & Poulter, 2010). To address power, SSM's CATWOE encourages groups to think about actors, owners, and customers (Checkland, 1981). SODA establishes a joint understanding of a problem by building shared group maps. These maps are either a composite of individual cognitive maps or a single map built by a number of participants. Both "can provide a means of enabling group members to jointly understand the perspectives of others, reflect on the emergent issues that are surfaced from them and begin to negotiate an agreed strategic direction" (Eden & Ackermann, 1998 p.73). In SODA, power is taken to be issue-specific rather than dependent upon position only; anticipated losers and winners are considered as are potential saboteurs and cynics (Eden & Ackermann, 2004b). SCA builds shared models to increase understanding of a situation. For example, decision graphs represent the linkages between different decision areas and the focus upon for the group, while the different options are represented on a compatibility grid (Friend, 2001). SCA integrates what is referred to as the 'policy stream' and 'technical stream'. The technical stream manages complexity of issues to develop confidence in results, while the policy stream manages conflicting positions of those involved to develop commitment to results (Friend & Hickling, 2005). SD includes participants in the process to develop fuller recommendations and increase the likelihood of their implementation (Weil, 1980). However, SD priorities may be closer to optimality than feasibility. The VSM considers power in the systems it models with the aim of understanding business functions, rather than to increase buy-in from powerful stakeholders. The purpose of DEA, simulation, and LP is not to explicitly envelope stakeholders or manage power relationships through their modelling process.

Pillar 2: Knowledge and involvement of stakeholders								
Q5 Does the approach build a qualitative model? *Q6 Can the approach build a model in a facilitated way?* *Q7 Does the approach focus on participants learning about the problem?* *Q8 Does the approach aim to produce politically and culturally feasible solution over optimal solutions?*								
Question	SSM	SODA	SCA	VSM	SD	DEA	Sim	LP
Q5	Yes	Yes	Yes	Yes	Yes	No	No	No
Q6	Yes	Yes	Yes	Yes	Yes	No	No	No
Q7	Yes	Yes	Yes	No	No	No	No	No
Q8	Yes	Yes	Yes	No	No	No	No	No

Figure 4 Pillar 2: Knowledge and involvement of stakeholders summary

2.4.3 Pillar 3: Values of model building

Does the model reflect the different social realities of the participants?

SSM builds multiple conceptual models based on different root definitions, thereby ensuring that different worldviews are considered when comparing the real world system with an idealised conceptual model. SODA represents multiple views in cognitive maps by either integrating individual maps or building group maps (Eden & Ackermann, 1998). SCA builds group models by participants writing their individual ideas so that these contributions can be compared and merged to ensure each participant feels that they participated directly in building the model (Friend & Hickling, 2005).

DEA, VSM, SD, simulation and LP typically represent a single (objective) reality therefore their purpose is not to represent different social realities. There are obviously exceptions to this general norm. For example, DEA can represent different realities through the weighting of inputs to outputs. Each DMU's efficiency is calculated using the most favourable transformation of inputs to outputs within any given weighting restrictions. Thus, different realities of what is efficient can be represented in the model. Sarrico et al. (1997) used differing weight restrictions to reflect different social realities of university applicants. Applicants identified qualitative ‘need to have’ questions to eliminate universities that did not meet their needs. Participants then considered their likely grades and selected criteria relevant to their university choice, which were used as outputs from the model. Finally, they rated relevant factors which were turned into weights restrictions. This data was used to produce a DEA model ranking universities for the applicants based on their unique value set, thereby reflecting different social realities of participants. However, in this instance, the final model was unique to a single participant and represented their own objective reality. The DEA model did not represent social realities of different participants simultaneously, nor was this the aim.

Is the model building process suitably generic so it can be transferred to multiple problem contexts?

All eight OR approaches discussed here have been successfully deployed in multiple and varied problem situations. For case studies of SSM see Checkland & Scholes (1990), for SODA see Eden & Ackermann (1998), for SCA see Friend & Hickling (2005), for VSM see Beer (1981), for SD see Forrester (1961), for DEA see Cooper et al. (2006), for simulation see Robinson (2004), and for LP see Winston (1994).

Does the approach rely on showing procedural rationality to give reliability to outcomes?

PSMs have to demonstrate that they are procedurally just without having hard data to economically ‘prove’ that the outcome is rational. SSM, SODA, SCA, and VSM cannot show economic rationality through quantitative analysis; instead, they show that the quality of data collection and substantial analysis follow a rational process to evidence results being reliable. SD, DEA, simulation, and LP can show economic rationality through the ‘proof’ of hard data and the reliability of outcomes is accepted based on proof of outcomes, not only inputs.

Does the model build a validated audit trail of the decision making process?

The audit trail of models and other artefacts (reports etc.) for all these OR approaches should show the rationale behind how and why outputs were reached. However, the process of validating the audit trail varies according to the approach. In SSM, SODA, and SCA, participants build the models and the audit trail so will have seen it develop throughout the process. Thus, participants validate the audit trail.

VSM, SD, DEA, simulation, and LP do not provide the same opportunity for stakeholders to continuously validate an audit trail, as the model is likely to have been built by an expert modeller. For these approaches, validation ensures that the model accurately and objectively represents the system being modelled. In both cases, a validated audit trail is built, albeit through different means.

Pillar 3: The values of model building								
Q9 Does the model reflect the different social realities of the participants? *Q10 Is the model building process suitably generic so it can be transferred to multiple problem contexts?* *Q11 Does the approach rely on showing procedural rationality to give reliability to outcomes?* *Q12 Does the model build a validated audit trail of the decision making process?*								
Question	SSM	SODA	SCA	VSM	SD	DEA	Sim	LP
Q9	Yes	Yes	Yes	No	No	Yes	No	No
Q10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q11	Yes	Yes	Yes	Yes	No	No	No	No
Q12	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure 5 Pillar 3: The values of model building summary

2.4.4. Pillar 4: Structured analysis

Does the approach structure knowledge through different stages of analyses i.e. is it a methodology?

SSM, SODA, SCA, SD and simulation structure knowledge through different stages of analysis. These methodologies guide the order of their stages and there may be flexibility in revisiting stages or switching between stages if sufficient knowledge has not been built.

LP and DEA are analytical methods that could form part of a wider methodology. VSM is not a methodology nor a method but an abstract model or blueprint for helping to design the structure of organisations (Mingers & Rosenhead, 2001). The principles of VSM, particularly those described in ‘Diagnosing the System’ (Beer, 1985), have been used to redesign or reorganise an organisation (for example, Walker, 1990). However, VSM itself has no distinct phases of analysis so it cannot be considered a methodology. Viable systems diagnosis (VSD) (Flood & Jackson, 1991; Flood & Zambuni, 1990) and VIPLAN (Espejo, Bowling, & Hoverstadt, 1999) are staged approaches using concepts from VSM, and so could be considered a methodology. Both implement a set of stages to diagnose faults present within the system-in-focus. In VIPLAN, the following steps are used to diagnose faults in organisations:

- Establishing organisational identity.
- Modelling structural activities.
- Unfolding of complexity: modelling structural levels.
- Modelling distribution of discretion.
- Modelling the organisational structure: study, diagnosis, and design of regulatory mechanisms (adaptation and cohesion).

(Espejo et al., 1999 p.661)

For the purposes of this analysis, the thesis only considers VSM and not the two variants above; therefore, VSM is not considered a methodology. In addition to VSM, DEA and LP are not methodologies, so questions 14 and 15 are not applicable to these three approaches.

Are there distinct phases for divergent and convergent thinking?

SSM, SODA, and SCA all have examples of structuring both types of thinking: SSM encourages divergent thinking by examining the transformation from different world views. SODA facilitators encourage participants to expand the richness of a cognitive/group map. SCA decision graphs help participants to widely consider how a range of issues are connected.

SD and simulation methodologies do not have stages of divergent thinking included within them. That is not to say that an analyst will not think divergently, but that divergent thinking is not explicitly built into the methodology.

Forcing participants to select the most relevant and accurate information to build a model implies that there are convergent thinking stages in all these approaches.

Does the approach manage knowledge through the methodology to avoid 'Knowledge Leaks'?

To avoid knowledge leaks an approach should ensure correct and relevant knowledge is used appropriately in later stages. For SSM, outputs from individual stages (e.g. root definitions) inform later stages (e.g. as the basis for conceptual models). For SODA, the knowledge is held in cognitive maps, which translate it from data collection through to analysis. As the knowledge is held in one place, it should be transferred from one stage to the next. The tools within the SCA integrate to create new knowledge, for example, decision graphs provide understanding of focal areas and lead to options graphs to represent different decisions to be taken, which lead to the compatibility grid of feasible decisions. The compatibility grid can be transposed into an options tree, and this knowledge can be held in STRAD2 software to ensure that it is properly recorded. In SD, the qualitative model identifies the structures and relationships between the elements under consideration within the system. Additional data is collected relating to the quantitative relationships (flows) among the elements in the system, which then allows the translation of the qualitative model (showing relationships between elements in the system) into the quantitative model, which in turn simulates the behaviour of the system in focus.

Knowledge leaks are minimised in this process as the qualitative model can be compared with the qualitative model to ensure that relationships are correctly represented. Simulation usually involves knowledge being created and held within a small team that uses four stages to ensure that knowledge is not lost (Robinson, 2004): capture data in conceptual models, code interactions into simulation software, experiment using a model, and implement findings.

Pillar 4: Structured analysis								
Q13 Does the approach structure knowledge through different stages of analyses? *Q14 Are there distinct phases for divergent and convergent thinking?* *Q15 Does the approach manage knowledge through the methodology to avoid 'Knowledge Leaks'?*								
Question	SSM	SODA	SCA	VSM	SD	DEA	Sim	LP
Q13	Yes	Yes	Yes	No	Yes	No	Yes	No
Q14	Yes	Yes	Yes	N/A	No	N/A	No	N/A
Q15	Yes	Yes	Yes	N/A	Yes	N/A	Yes	N/A

Figure 6 Pillar 4: Structured analysis summary

2.5 Evaluation of framework and discussion points

This section appraises the four pillar framework based upon its evaluation of the eight OR approaches. This provides a basis to understand if the four pillar framework provides an adequate tool for evaluating if an approach demonstrates the defining features of PSMs. This section examines the four pillar framework in a wider context by developing initial discussion points (shown in italics), which are revisited in the Discussion Chapter of the thesis.

Only the three established PSMs answered yes to all 15 questions and, according to the framework, could be classified as PSMs. This suggests that the framework can be effective at differentiating between PSMs and other OR approaches. Therefore, the framework could be applied to fringe PSMs as a way to evaluate if they have the attributes of a PSM. As the framework was built on the assumption PSMs make different assumptions philosophical assumptions to non-PSMs. *Discussion Point 1 considers if Rosenhead and Mingers were correct in* *asserting PSMs have different underpinning assumptions when compared with other approaches.*

A perceived weakness to the development of the framework is the circular argument in classifying three PSMs using the framework. The literature on these three PSMs led to the development of characteristics and questions and was then used to decide if the PSMs satisfied their own criteria. Critics could argue that this self-referencing approach presents a tautological argument and does not demonstrate that the established approaches are PSMs, but merely that they have characteristics that have already been identified in the literature. However, this misses the point of the framework and the reason it was applied to original PSMs. The framework has been developed to understand the classification of approaches where clarity does not exist about its status as a PSM. The inclusion of three PSMs in the analysis was a test of the framework rather than a test of the eight selected approaches. The important finding is the ability of the framework to delineate non-PMSs from PSMs, not the individual classifications of established PSMs. This again explains why the answers to the questions in the framework were relatively short as not to limit repetition of the argument.

All five non-PSMs answered ‘no’ (or were not applicable) to the following questions: 7) Does the approach focus on participants learning about the problem?; 8) Does the approach aim to produce politically and culturally feasible solutions over optimal solutions?; and 14) Are there distinct phases for divergent and convergent thinking? This might indicate that these are critical questions and the framework could be reduced to only three questions. However, the analysis only examined five non-PSM approaches; there could be other approaches that are not included within the analysis that would answer yes to some of these three questions without fulfilling all 15 criteria identified by the framework. For example, group brainstorming onto flipchart paper focuses on participants learning through sharing and building knowledge. However, brainstorming does not meet the requirements of many of the other questions, for example, 13) Does the approach structure knowledge through different stages of analyses i.e. is it a methodology? The framework's strength is its breadth, which has been developed by grounding it in the four philosophical constructs; reducing the framework would cause it to lose this strength as it would become no more useful than some of the descriptive definitions in Section 2.2.2.

All eight approaches answered 'yes' to the following questions: 4) Does the approach model an identifiable system? 10) Is the model building process suitably generic so it can be transferred to multiple problem contexts? and 12) Does the model build a validated audit trail of the decision making process? There could be an argument to eliminate these seemingly superfluous questions from the framework. However, the argument that these three questions did not filter out any of the five tested non-PSMs and therefore should be excluded is based upon a fallacy. Questions 4, 10, and 12 must be retained as they are all distinguishing characteristics of OR. Given that all eight approaches are established OR approaches, we would expect them to answer yes to questions 4, 10, and 12 as these are characteristics of OR approaches and not just PSMs. All eight approaches are taken from OR and should therefore demonstrate the features identified in questions 4, 10, and 12. For example, question 10 establishes if the approach is generically applicable to multiple problem contexts, this will be true for all established approaches but is a critical criterion for new methodologies which may have few actual applications. Without a large number of historic uses in differing problem contexts, how can an approach show that it is suitably generic to be considered a PSM? This is considered in Chapter 4 of the thesis in relation to WASAN.

Finally, the framework identified 'knowledge leaks', a new methodological concern when designing a PSM. Staged methodologies have been discussed throughout the PSM literature (Checkland & Holwell, 1998; Friend & Hickling, 2005) as has knowledge creation using PSMs (Eden, 1992; Franco, 2013), but to this is added the importance of ensuring relevant and correct knowledge is not lost through misrecordings between stages. *Discussion Point 2 considers if the concept of knowledge leaks is useful for practitioners and researchers to consider when designing an intervention.*

This section has presented and tested a framework to assess what is a PSM. The four pillar framework constitutes Contribution A of the thesis. The 15 questions from the framework also answer RQ1: *"What are the defining philosophical, theoretical and methodological features of PSMs?"* The four pillar framework is used in Chapter 4 to answer RQ3: *"How can an approach show it has the defining features of PSMs?".* However, before that can be addressed, we must first understand WASAN, the context in which it was developed, and the process of that development. From there we can understand how to develop WASAN further.

The section also identified two Discussion Points which will be considered in the Discussion chapter alongside the other Discussion Points developed throughout this thesis. The Discussion chapter will broaden the theoretical and methodological contributions of this thesis by understanding the findings in a wider context.

To learn more about the defining features of PSMs, this research project is concerned with the development of the theory and methodology of one such fringe PSM, WASAN. The research project aims to position WASAN as a generic PSM; however, without an agreed framework by which to assess WASAN's PSM credentials, this claim cannot be made. Therefore, Section 2.4 has been dedicated to understanding the common features of PSMs to aid answering RQ1 and deliver Contribution A of this thesis to "develop a framework to assess what is a PSM".

2.6 WASAN

This thesis aims to provide greater knowledge on the theory and methodology of PSMs. To do this, the research project considers the philosophical, theoretical, and methodological development of WASAN. This is shown through Contribution B, "Methodological development of WASAN into a generic approach" and Contribution C, "An application of the framework to WASAN to understand if it is a PSM", (developed in Chapter 4). Making both these contributions will lead to knowledge about WASAN and PSMs in general. This section of the literature review is concerned with the current literature on WASAN to contextualise the research and show why the approach is a good candidate to develop in order to learn about PSM theory and methodology. This review focuses on three dimensions: first, the initial need for developing WASAN, examining the problem context and reasons for development; second, the philosophy of WASAN, the assumptions WASAN makes about ontology, epistemology, and axiology; and third, the WASAN methodology, how WASAN translates these three philosophical assumptions into methodology. To understand these three elements, three papers published on WASAN (Shaw & Blundell, 2008, 2010, 2014) have been reviewed. This review expands and reinterprets these papers to lay the foundations for the philosophical development of WASAN by explicitly stating the current WASAN philosophy and how this is translated into practice by the individual tools and methods constituting the WASAN methodology. The 2010 paper and 2014 paper both introduce WASAN and show how it was operationalised within a case study. The 2008 paper describes a specific element of WASAN (WAZOP), which was used as a forerunner of the WASAN methodology. As this element is now included within WASAN and the context is the same as the other two papers, the thesis assumes that knowledge and learning derived from the 2008 paper is also applicable to WASAN, albeit slightly narrower in focus.

2.6.1 Initial development of WASAN

In the UK, the estimated cost of remediating the waste from the UK nuclear industry is in excess of £45bn and will take over 120 years (DECC, 2011). Management of nuclear waste is an expensive, complex, and intergenerational problem (Taebi, 2012). Therefore, the management of nuclear waste is governed at national and international levels. The International Atomic Agency, through the 'Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management' requires member states to report on their waste and waste management regimes regularly (DECC, 2011). The European Commission requires member states to adopt a strategic view to waste management (EC, 2011). The significant cost and risks involved encourage waste-avoidance strategies (Bautista-Lazo & Short, 2013) to ensure that lower volumes/hazards require eventual disposal (Hatfield & Ott, 1993), which of course leads to lower costs associated with disposal and management of hazardous waste.

To better understand and eventually manage nuclear waste, the Nuclear Installations Inspectorate (NII) commissioned the development of a decision making methodology that could be used by managers of nuclear sites to analyse the reduction of avoidable radioactive waste (Shaw & Blundell, 2010). The methodology was developed by one process expert with a background in systems thinking and PSMs and one content expert from the Office of Nuclear Regulation. The development of WASAN can be viewed as a development of a waste management philosophy, where principles about waste management were developed. Analytical techniques and methods were drawn from industry, regulation, and academic theory and practice to build an approach to fit this WASAN philosophy. This search for individual analytical techniques that could be ported into WASAN was compared to Ormerod's (1997) notion of smart bits by Shaw & Blundell (2010).

Smart bits are the individual techniques and methods that comprise an approach; a methodology could be deconstructed into individual smart bits such as the individual seven stages of SSM. For Ormerod, these smart bits are an “array of OR techniques” (Ormeod 1997 p.1047) that help OR to be “deployed in a wide range of one off problems” (Ormerod 1997 p.1047). Therefore, in the development of WASAN, individual smart bits were taken out of the context and philosophy of an existing approach and used under the new WASAN philosophy. The unique combination of smart bits in their totality comprise the WASAN methodology—that is, the WASAN approach as an emergent property of the specific combination of smart bits supported by the WASAN philosophy. This is supported by Jackson (2003 p.43) who writes that “methodology is not detachable from the philosophy/theory of the particular systems approach or, therefore, from the approach itself. Methods, however, concerned as they are with achieving more specific procedural outcomes, are detachable and can be used in the service of other systems approaches with varying degrees of success or failure.” In essence, individual techniques or methods that perform specific procedures within a methodology can be detached from that methodology and used elsewhere under a new philosophy alongside other methods which share and contribute to the same philosophy. If all of the methods fit together and successfully embody the new philosophy, then the wider methodological goals of the new approach can be achieved. For the remainder of this thesis, these individual methods are termed smart bits in favour of using Jackson's (2003) term method. Omerod’s definition of smart bits and Jacksons’ definition of ‘method’ imply that these terms could have been used interchangeably in the thesis; however, ‘method’ is defined differently by other authors so the term smart bits seems less ambiguous.

2.6.2 The philosophy of WASAN

This section of the literature review considers the philosophy of WASAN by reviewing the current WASAN literature. This presentation of the philosophy of WASAN in the section is novel as the assumptions underpinning WASAN are deconstructed into ontology, epistemology, and axiology. Presenting the current information on WASAN in this manner will help to identify a clear underpinning philosophy, which will be needed in order to further develop the approach. All three WASAN papers mention an underpinning philosophy of the approach; however, none of them show how the WASAN philosophy is translated into practice through the methodology. To develop WASAN further, this thesis should first understand the WASAN philosophy to ensure any future developments to not alter or distort this philosophy beyond its original intention. The review identified five explicit references to the philosophy of WASAN:

- “Waste can be reduced through detailed formal thinking to identify high-impact deliverables that are carefully implemented” (Shaw & Blundell, 2010 p.355).
- “Prevent waste generation by understanding behaviour of source material in facility-in-focus” (Shaw & Blundell, 2008 p.233).
- “Closer management of up/downstream facilities which interact with facility-in-focus should aim to prevent fluctuations in their operations having negative effect on facility-in-focus” (Shaw & Blundell, 2008 p.248).
- “Identify best portfolio of action that will severely limit the course materials generation of avoidable waste resulting from disruptions in facility-in-focus that are caused by mal-operations in up/downstream operations” (Shaw & Blundell, 2008 p.233).

- WASAN takes the philosophy that waste disposal should be 'As Low As Reasonably Practicable' (ALARP) taken from the Health and Safety Executive's safety-based philosophy (HSE, 2001) - (Shaw & Blundell, 2014)

These can be condensed to five statements that sum up the underpinning assumptions of the WASAN philosophy:

1. Waste has a negative impact upon a facility, but through formal thinking we can understand the behaviour of waste.
2. By understanding waste, we can manage waste maloperations and fluctuations that increase it and how it impacts a facility-in-focus.
3. Formal thinking can be extended to up/downstream of the facility-in-focus.
4. The aim of WASAN is to produce the best portfolio of high-impact actions to reduce the impact of waste upon the facility-in-focus.
5. The actions should embrace the principle of ALARP.

In addition to these explicit references to philosophy, there are additional regulators principles of what is good practice decision making in the nuclear industry (HSE, 2005), which WASAN had to include within the decision making process to satisfy the NII. These principles state decisions are

a) Auditable: decisions can be traced back to source years later.
b) Transparent: the decision and the process are understandable.
c) Clear: no misinterpretation of the content of discussions or the outcome.
d) Strategic/planned: decisions are considered locally but recognized within the wider strategy.
e) Managed: effective leadership of the decision making process and delivery of actions.
f) Optimised/minimised: a streamlined process which could be replicated.
g) Integrated: able to explore the wider waste-producing system.

h) Delivered: a practical outcome of feasible recommendations.

In addition to these principles Shaw & Blundell (2010) add the following principles of good practice:

i. Learning: building understanding about the wider waste-producing system.
ii. Agreeing: negotiating the best agreeable outcomes from available insights.
iii. Facilitation: providing structured support to stakeholders' analysis, learning, and negotiation.
iv. Useable: the method is usable by novice facilitators/practitioners, essential for national roll-out.
v. Systemic analysis: rigorous analysis of system's far-reaching inter-relationships.

The statements 1–5, a–h, and i–v show the underpinning philosophy of WASAN. Philosophy is comprised of assumptions relating to ontology (what is assumed to exist), epistemology (the nature of knowledge), and axiology (values of problem solving) (Guba & Lincoln, 1994). WASAN's ontology is represented in statements 1–3. These statements identify that waste has a negative impact on a facility-in-focus. However, this waste can be managed to reduce this impact by examining mal-operations in the facility-in-focus and fluctuations from its upstream and downstream channels. WASAN's epistemology is represented in statements i–v. Knowledge is created through learning, agreeing, and facilitation. The methodology is usable and conducts a systemic analysis. Finally, the axiology of WASAN is represented in statements 4 and 5 and a–h. WASAN should value producing high-impact recommendations regarding the reduction of waste within the facility-in-focus. These recommendations should be deliverable and prioritise waste reduction, that is, ALARP. In addition to these values relating to the output, WASAN also values the process of getting to these outputs. Therefore, the decision making process should have a clear transparent audit trail that manages waste and is integrated with the wider goals of higher order systems. While the three papers examined the philosophy, it was never deconstructed in this manner. The deconstruction of WASAN in this manner is necessary for the further development of the approach; a clear understanding of the WASAN philosophy is required to achieve both Contributions B and C.

The core principle that underpins the WASAN is a waste management philosophy. This philosophy provides guidance on what should be analysed (ontology), the type of knowledge that is needed to reduce waste (epistemology), and the values that judge if the outputs and process used are good (axiology). These assumptions are translated into real life using the fourth assumption from Guba & Lincoln (2005)—methodology. The development of the WASAN methodology "was characterized by the adoption and amalgamation of principles, documents, tables, language and techniques from industry, regulation and academia" (Shaw & Blundell, 2010 p.351). These techniques constitute the smart bits used to build the methodology. Seven smart-bits already embedded within WASAN are reviewed below. The review examines what the smart bit achieves, its influences or roots, and how it fits in with the WASAN philosophy. A reference to the ontology, epistemology, or axiology and corresponding statement from the above 18 statements in parentheses is made as, for example, if the smart bit was in keeping with the axiological principle of ALARP, then (5) would be the reference as ALARP is from statement 5.

2.6.3 Smart bits and the development of the WASAN methodology

This section deconstructs the current WASAN methodology into seven smart bits. The discussion of each smart bit comprises three parts. First, information from the three existing WASAN papers which describe the smart bit, its purpose, the approach, and how the smart bit achieves that purpose. Second, information from the existing literature showing influences for the smart bit; this shows how the smart bit was developed outside of WASAN and increases understanding of the smart bit. This will help when considering any further developments required to make the smart bit generic. Third, how the smart bit contributes to the WASAN philosophy as described in Section 2.6.2; identifying this link is the novel contribution in this section. To highlight these contributions, they are presented in a box at the end of each paragraph and then summarised at the end of this section. Understanding how each smart bit contributes to the WASAN philosophy will provide an audit trail to check when these smart bits are developed further in Chapter 4; we can see if the smart bits have been changed in a manner that would compromise the WASAN philosophy.

The first smart bit considered is from Stage A of WASAN, 'Define System Boundary'. This is described by Shaw & Blundell (2010 p.352) as "Defining the system's boundary by agreeing the scope of analysis e.g. process facility, wastes". Here, WASAN adopts a systems approach in understanding the boundary of the analysis. A systems approach has grown out of several different intellectual traditions and so taken to mean a multitude of different things (Richardson, 1991). Therefore, here we draw from Jackson (2003), who writes that systems approaches state that there is a need for holism, not focusing on only one element of a problem but recognising an entire interconnected system of elements which all interact with one another and must be considered as a whole to be understood and improved. Kelly (1998) provides four advantages to a systems approach. First, the approach facilitates the explicit identification of linkages within the system and understanding of system behaviour over time. Second, the process of model building points to areas where relationships may be poorly understood, which then can then be a focus for information collection and knowledge development efforts. Third, it supports learning about the system and so changes the mental model of decision makers. Fourth, it provides a common language to support communications across disciplines, particularly if the specified approach has a defined lexicon. These four benefits are all portable to a waste management philosophy. For example, Musee, Lorenzen, & Aldrich (2007) adopt a systems approach—the minimisation of waste in the wine industry. Shaw & Blundell (2010 p.352) have justified this systems approach to waste management based on “the systemic nature of waste production”.

The systems approach is a formal thinking approach (1) which can be extended to thinking about the up/downstream activities and the facility-in-focus (3) and thus feeds into the ontological position of WASAN. It also is a form of systemic analysis (v), so it fits into the epistemological philosophy of WASAN.

Having justified a systems approach, the second smart bits used in WASAN is examined—the system boundary from Stage A. As identified by Kelly, the definition of a system provides a common understanding through a single definition of the system. This draws from root definitions in SSM (Checkland & Scholes, 1999); the word ‘root’ “conveying that this is only one, core way of describing the system” (Checkland & Poulter, 2010 p.219). Through group negotiation, we are able to obtain a commitment from stakeholders to this core definition of the system (Eden, 1992). For SSM, root definitions should define the following six elements: Customers, Actors, Transformation, Worldview (Weltanschauung), Owners, and Environment, which are collectively referred to as CATWOE. However, for WASAN this was not appropriate: “SSM is concerned with human activity systems” (Pidd, 2009 p.90); in contrast, WASAN is concerned with technical waste-producing systems. Like a root definition, WASAN aims to uncover alternative viewpoints and build initial agreement about the definition of the system through group negotiation (Shaw & Blundell, 2010), but does not use the same taxonomic categories to focus on this negotiation as SSM. The negotiated and agreed definition for WASAN encompasses the following aspects:

- The source-matter (SM) that causes waste.
- The (A)im in processing the source-matter.
- Engineering, physical, managerial (S)afeguards: to identify activities that prevent avoidable waste so actions may strengthen (avoid compromising) these.
- The avoidable (W)astes which the source-matter creates.
- Definitions for each waste may identify the following aspects:
- The avoidable (W)aste: to identify the material being defined.
- The (R)easons the waste is generated.
- The physical (F)orm of the waste.
- Optimal (C)onditions for managing the waste.
- (B)ehaviour of the waste.
- Additional (A)ssumptions about waste minimisation.

(Shaw & Blundell, 2010)

Defining these core elements for WASAN constitutes the boundary of the system and identifies the wastes to be analysed in Stage B.

> The system definition is agreed through facilitation (iii), where participants learn (i) about the system as a group meeting the epistemological aims of WASAN. The system definition also provides a clear (c), transparent, (b) and auditable (a) account of the system, thereby meeting the axiological goals of the WASAN philosophy.

The third smart bit is from WASAN Stage B ‘Analyse Operations’. This analysis focuses on how WASAN structures the analysis of avoidable waste. The aim of Stage B “is to systematically identify issues in minimising a source-matter’s generation of waste” (Shaw & Blundell, 2010 p.353). Each waste is analysed in turn using a variety of taxonomic keywords. Keywords function as prompts to structure how participants think about the waste and how the waste could be managed. “Thus, keywords were trialled as a facilitator’s smart-bit to structure discussion on waste management issues for each waste” (Shaw & Blundell, 2010 p.353). Using different keywords for each waste results in different conversations, identifying different issues, and results in different candidate actions (Shaw & Blundell, 2010). Structuring the analysis of a system or decision area using keywords is not new or unique to WASAN. Keywords have been used as an analytical technique to structure the thoughts of participants in a variety of different approaches. One most widely used and known analytical technique by OR practitioners is SWOT analysis (Munro & Mingers, 2002) SWOT analysis as used by Dyson (2004) in the development of strategy at the University of Warwick is an example of keyword analysis. Users systematically think about a unit in terms of the following four keywords: strengths, weaknesses, opportunities, and threats. Like in WASAN, each keyword structures participants’ thoughts about the situation and prompts areas for consideration. SWOT is not alone in the other widely used and cited theories based on keywords as prompts, including Porter’s five-forces analysis (Porter, 1979) which considers the competitiveness of an industry based on the keywords/phrases threat of new entrants, bargaining power of buyers, threat of substitutes, bargaining power of suppliers, and industry rivalry. Keywords are also used in other qualitative modelling approaches such as SCA, where actions are thought of in terms of technology, organisations, process, and product in the A-TOPP framework discussed earlier (Friend & Hickling, 2005). Finally, the use of keywords to reduce waste can also be found in lean where the seven types of waste are commonly used as keywords in manufacturing to structure enquiry regarding process improvement (Schonberger, 1986). We see that the smart-bit of keywords is an established technique for structuring participants' thoughts about an issue during divergent thinking phases.

> Keywords help to understand how we can manage waste (2) by meeting the ontological principles of WASAN. They help participants to learn (i) about the management of waste, and are a usable (iv) easily understandable technique for novice facilitators (iii), thereby meeting the epistemological principles of WASAN. Finally, keywords provide a clear (c), transparent (b) audit trail (a) of decision making.

Stage B is divided into two parts: B1 internal wastes and B2 external wastes. External wastes are those entering the system from defined upstream or downstream channels. Internal wastes are those that occur within the system as defined in Stage A. These two categories of waste both undergo a keyword analysis; however, the keywords used differ depending on if the waste being analysed is internal or external (Stages B1 or B2). The two different stages have separate keywords and therefore are considered separate smart bits. The keywords for external analysis, smart bit four, are drawn from the government-backed waste management hierarchy. The hierarchy was chosen as it is accepted by most industrialised nations (Bai & Sutanto, 2002), including England (Cabinet-Office, 2002). The hierarchy comprises seven keywords: avoid, minimize, reuse, recycle, recover, treat, and dispose [Figure 7 from (Shaw & Blundell, 2010)]. The keywords are placed in order of preference: those at the top of the hierarchy are more preferable for waste reduction than those lower down. This reflects that the negative impact on a wider system is smaller with actions from keywords at the top of the hierarchy, when compared with actions from the keywords nearer the bottom.

Using the waste management hierarchy as keywords on the upstream and downstream operations from the facility-in-focus ensures that formal thinking is extended to up/downstream channels (3). The waste management hierarchy also embraces the axiological principle of the minimisation (f) of waste.

Hierarchical level	Keyword
Avoid (most preferable)	- Avoid - Minimize
Reuse	- Reuse (in its current form) - Recycle (process waste so it is reusable) - Recover (extract energy or material from waste to reuse/recycle)
Dispose (least preferable)	- Treat (prepare waste for disposal) - Dispose

Figure 7 Waste management hierarchy (from Shaw & Blundell, 2010)

The internal analysis combines two analytical smart bits transportations: smart bit five and sensitivity analysis, smart bit six. Transportation requires participants to identify and define transportation into/out of the process facility; the definition should identify the potential area where the transportation might be operating outside of its intended parameters (mal-operations) or might cause a mal-operation. The definition of these transportations can include the following aspects:

- The (W)aste: to identify the material being transported.
- How waste is (T)ransported between facilities: to identify the route and technology associated with the transportation, as each might mal-operate.
- Issues in the (M)anagement of the transportation: to identify how the transportation is managed, and opportunities for mal-operation.
- Other mal-(O)perations: to identify other mal-operations that complicate transportations.
- How (U)p/(D)ownstream facilities may affect transportation.

(Shaw & Blundell, 2010)

This recognises the ontological position of WASAN that formal thinking should be extended to the upstream and downstream channels from the facility-in-focus (3).

Smart bit five is a qualitative sensitivity analysis. Sensitivity analysis is widely used in OR. In quantitative OR, Albright & Winston (2007 p.121) define sensitivity analysis as “seeing how the optimal solution changes as various input values change”. For example, in linear programming, as constraints change, the convex hull (set of feasible results) may also change. This might change the optimal solution; similarly, a change to the objective function could also shift the optimal solution. A sensitivity analysis on the constraints can be used to understand the incremental value of a scarce constraint. For example, in a production schedule, if one hour of additional work yields an additional £10 in the optimal solution, then if the cost of labour was less than £10/hour it is worth increasing hours worked. Pidd (2009) provides an example of sensitivity analysis in decision tree analysis. The decision tree evaluates a set of options based on expected outcomes and the probability of those outcomes coming to fruition. The sensitivity analysis assesses how changes in the initial assumptions affect which option is the best decision. Sensitivity analysis can be used in simulation to understand how mal-operations can affect a system’s performance (Greasley, 2004). In all three approaches, the sensitivity analysis is used to quantitatively understand how changes or deviations to the expected system behaviour will alter the ‘best’ ways to respond to the system. WASAN also uses a sensitivity analysis to understand how mal-operation from transportations will affect the system. However, unlike the other approaches and in keeping with the WASAN philosophy, the sensitivity analysis is qualitative. Therefore, in respect to the sensitivity analysis, WASAN is more closely aligned to the engineering design technique HAZOP than the quantitative OR approaches discussed above. HAZOP is a “procedure meant to identify how a process may deviate from its designed intent" (Dunjó, Fthenakis, Vílchez, & Arnaldos, 2010 p.20) and how this deviation affects the performance of the system. It was developed based on the critical examination technique, which is a formal technique for examining an activity and generating alternatives by asking 'What is achieved?', 'What else should be achieved?', 'Where is it achieved?', 'Who achieves it?', and so on (Kletz, 1997). The means to generating these alternatives (asking qualitative questions about a process) is used in HAZOP. However, where the critical examination technique was designed to generate alternatives, HAZOP was modified to generated deviations (Kletz, 1992) and was first published by Lawley (1974). Executing HAZOP relies on using keywords, such as more or less, combined with process parameters, such as temperature, flow, and pressure. The aim of this is to reveal potential deviations from normal procedure within an operation, such as less flow, more temperature, (Dunjó et al. 2010). The procedure is applied in a particular part or operation of the system. Having determined the deviations, the expert team explores their feasible causes and possible consequences. For a range of HAZOP keywords, see Tyler, Crawley, & Preston (2000). For every pair of cause-consequence, safeguards must be identified that could prevent, detect, control, or mitigate hazardous situations. Finally, if the safeguards are insufficient to solve the problem, offering recommendations must be considered. By decomposing complexity, the method aims to allow complexity of system behaviour and waste production to be better understood (Shaw & Blundell, 2008). These benefits are transferable to the internal sensitivity analysis in WASAN. WASAN can take the technique of applying keywords to understand system behaviour under deviations in specific processes and use similar keywords to qualitatively understand how deviations in specific transportations affect system behaviour. Where the quantitative approaches used numbers to understand deviations from expected behaviours, WASAN can learn from HAZOP to understand these deviations qualitatively. 'Without numbers to populate our model, we estimated qualitative severities of outwith-design (e.g. more/less transportations) and qualitative estimates of their effect' (Shaw & Blundell 2010). The sensitivity analysis is structured using a keyword analysis where the keywords structure participants to think how the system would perform if transportations were outside the expected range. The keywords shown in Figure 8 help to understand the system behaviour during mal-operations. This is important because when a system deviates from its intended design, it is most likely that avoidable waste will be generated.

This encompasses the ontological position that emphasises that we can understand and manage how mal-operations affect waste generation (2).

- Nothing
- Less than normal
- Part of the normal waste
- More than normal
- Other wastes (as well as normal)
- Other wastes (instead of normal)
- Reversing

Figure 8 Sensitivity analysis keywords (from Shaw & Blundell, 2010)

Smart bit six is the action evaluation grid (AEG) used to evaluate candidate actions in Stage C. Stage C begins the convergent thinking phase of the analysis, thereby reducing the number of candidate actions generated in Stage B to those which are most likely to have the highest impact. "The aim is systematically analyse candidate actions to identify emergent themes and agree high impact deliverables" (Shaw & Blundell, 2010 p.355). Participants are faced with a set of potential candidate actions and have multiple potential criteria on which to base a decision. To rate candidate actions, WASAN developed smart bit seven called the Action Evaluation Grid (AEG), which draws inspiration from the Enforcement Management Model (EMM) (HSE, 2005). EMM is a structured methodology to help HSE

Inspectors decide if there are any laws that have been broken (HSE, 2005). The EMM "is structured by a set of questions that inspectors ask to evaluate the situation, providing criteria (e.g. potential for harm) and measures (e.g. possible, probably, remote) for the responses" (Shaw & Blundell, 2010 p.355). This is similar to multi-criteria decision making (MCDM) (Zionts, 1979) which recognises that most problems have conflicting objectives. MCDM (occasionally called MCDA) is a well proven tool with generic applicability. The AEG draws on using multiple criteria for evaluating each action and the qualitative aspects of the EMM to produce a tool which can effectively evaluate the actions generated in the earlier stages of WASAN. The AEG takes this structure of qualitative questions with responses and pairs it with the aim to reduce waste management in ALARP. "The AEG can deconstruct the capability of proposed actions using a similar structured approach to the EMM to reduce waste to ALARP" (Shaw & Blundell, 2010 p.355). The AEG consists of three qualitative criteria, each with their own three categories. The AEG is used by a group that systematically works through each candidate action, agreeing which category to place each action on for each criterion. In Shaw & Blundell's (2010) case study, the following three criteria and categories were applicable:

- Criterion 1—What is the realistic benefit from implementing the recommendation?
  - Categories: significant waste savings (most preferable); lesser significant waste savings; minor waste savings (least preferable).
- Criterion 2—How sure are we that the recommendations will work adequately?
  - Categories: well defined and proven (most preferable); adequately defined and other analogues exist; no analogues exist and development could be required (least preferable).

- Criterion 3—How long to reach the point of implementation?
    - Categories 3: within 1 month (most preferable); 1–3 months; +3 months, but within the financial year; beyond the financial year (least preferable).

(Shaw & Blundell, 2010)

The positioning of each action on the grid determines if it is carried forward to the next stage or discarded.

The AEG smart bit supports the epistemology of WASAN as it supports group learning (i) through agreeing (ii) on the placing of actions on the grid. The simplicity of the grid means that it is usable (iv) even by novice facilitators (iii). Axiologically, it aims to produce the best portfolio of high-impact recommendations (4) through the principles of ALARP (5). The completed AEG is an artefact that is a clear (c) and transparent (b) audit trail (a) that looks to minimise waste (f) production and ensure that actions are deliverable.

The seventh smart bit is the higher authority signoff from Stage D which aims "to evaluate actions at a global level (e.g. against funding constraints and strategic priorities), and programme those into a monitored work plan to deliver global priorities" (Shaw & Blundell, 2010 p.356). This assumes that higher-level bodies are responsible for setting global strategic goals and priorities for the system. Higher authority signoff draws on the notion of vertical recursion, which states that "any viable system contains and is contained, in a viable system" (Beer, 1979 p.118). In other words, the facility-in-focus will be embedded within a higher authority system, which along with having authority over the facility-in-focus also has authority over the up/downstream systems from the facility-in-focus. To ensure that decisions made locally are aligned with the wider strategic aims of the global system, the set of recommendations along with supporting evidence and audit trail are presented to a higher authority for a final decision and agreement.

Pushing the final decision up to a higher level authority reveals the axiological principle that decisions are managed (e), strategic, and planned (d) and integrated (g) in terms of the wider operational units, and that agreed recommendations are deliverable (h).

Table 3 summarises the new contributions of this section, listing each of the seven smart bits presented in the above section. Columns 3, 4, and 5 show where and how the smart bit translates philosophy into practice by linking each smart bit back to the philosophical statements of ontology (statements 1-3), epistemology (statements i-v), and axiology (statements 4-5 & a-h) presented in Section 2.6.2. Each of the 18 philosophical statements that constitute the WASAN philosophy are included in at least one of the smart bits. In addition to this, none of the smart bits contradict the statements identifying the WASAN philosophy. It is not necessary for each smart bit to embody all of the philosophical statements, as they are tools which in their totality reflect the WASAN methodology. Therefore, at an individual level, each smart bit only needs to represent one or more statements. For example, the AEG creates an artefact in the finished grid, which represents the decision making process and therefore embodies statement a (Auditable). This single process does not also have to explore the wider waste producing system (g) as this is achieved elsewhere by another smart bit. Table 3 also demonstrates the smart bit approach to the development of WASAN by listing the influences of each smart bit in column 6. The smart bit approach to development of methodology is explored further in Chapter 4.

Number	Name	Ontology	Epistemology	Axiology	Influenced by
1	Systems Approach	1, 3	v		
2	System Boundary		i, iii	a, b, c	Root Definitions
3	Keywords	2	i, iii, iv	a, b, c	SWOT
4	WMH	3		f	
5	Sensitivity Analysis	2			HAZOP, Simulation
6	AEG		i, ii, iii, iv	4, 5, a, b, c, f	EMM, ALARP, MCDM
7	Higher Authority Signoff			d, e, g, h	Vertical Recursion

Table 3 Summary of smart bits

2.6.4 Justification of WASAN

To ensure WASAN is the most appropriate methodology for the study of these phenomena the approach was compared with the other fringe PSMs identified in Table 1. For brevity the comparison between WASAN and general morphological analysis (GMA) is included below, this is precluded by a short description of GMA.

The analysis phase in GMA begins by identifying and defining the most important dimensions of the problem situation to be investigated. These dimensions make up either decisions or outputs from the decision conditions (Ritchey, 2006). Users then identify the possible solutions from within these areas, by selecting a range of mutually exclusive conditions or states for each dimension. This maps a known solution space.

Each pair of conditions across the different dimensions is then examined to identify the extent to which the pair of conditions can co-exist, that is do they represent a consistent relationship. This checks the internal consistency of the model. This technique limits the possible options within the decision space and can typically reduce the morphological field by 90% or even 99%. The resultant morphological field becomes an inference model, in which a parameter (or multiple parameters) can be selected as “input”, and any others as “output”. Thus the field is turned into a laboratory with which users can designate initial conditions and examine alternative solutions. (Ritchey, 2006). GMA has been used in a range of contexts, Ritchey (2011) identifies several case studies including: evaluating preparedness for chemical accidents; anonymous communication over the internet; Nordic energy scenario's; multi-hazard reduction strategies; and, electricity grid sabotage scenarios.

There are similarities between WASAN and GMA, firstly both models are built with expert facilitation, that is there are a range of context experts working with one or more process experts. In addition the model takes the form of a matrix with different possibilities populating the matrix. However the approaches are markedly different in their process. GMA aims to capture the entire solution space in the model creating an exhaustive list of scenarios ahead of time, whereas WASAN focusses on modelling a partially unknown upstream system. The data that populates the matrix grid in GMA is a range of possible states or conditions for each dimension, these are all possible, the aim for GMA is to identify desirable combinations of these different conditions or states that are internally consistent.

The data populating the matrix during the stage B1 keyword analysis in WASAN is a set of hypothetical actions prompted by analysis of the wastes using the corresponding keywords. That is each action identified through the analysis is independent of all other actions, the matrix represents a whole range of different actions which could be pursued on their own or in combination with other actions.

In an emergency management setting these two approaches would be used very differently, GMA would seek to identify the set of conditions and outputs that are desirable for the situation across all dimensions. WASAN will identify a range of possible actions which need to be evaluated further before action.

Hussain (2013) identified several weaknesses of GMA first, GMA requires experienced facilitation, second producing GMA models requires significant time from modellers and content experts working together to develop and use the models. Third there is a limitation of group size in GMA, with 7-8 participants typically regarded as the maximum. Finally GMA requires dedicated computer support to aid development and analysis of the morphological field. With respect to WASAN two of these limitations are also applicable. WASAN also requires expert facilitation and significant time to develop a model. In addition WASAN requires appropriate computer support, however the software required does not extend beyond a spreadsheet which should not be a limiting factor. WASAN is only applicable where there is an appropriate upstream system and there is a waste which should be minimised. Therefore GMA is potentially a more flexible approach. However as with any methodological choice it is important to choose the most appropriate approach given the problem situation.

Given there is an upstream system in the police context and waste is the main concern of the management at the UK Police Force WASAN is selected here over GMA or any of the other approaches.

2.7 Recursion in qualitative OR

Contribution D—"Show WASAN makes contributions to the theory of PSMs by showing how horizontal recursion can be used to represent interactions and meta-systemic issues across multiple modelled systems". The concept of recursion and recursive systems was developed in WASASN to show how WASAN can contribute to the PSM theory. It is no coincidence that recursion is a central principle in Question 2 of the four pillar framework. To make the case for including WASAN as a PSM, the project wanted to show that along with sharing the same defining criteria as PSMs, WASAN could advance these central features and therefore make contributions to the body of the PSM theory. WASAN contributing to the theory of recursion shows commonality between WASAN and the existing PSMs and how WASAN influences other PSMs. For the author, this final proof that WASAN is a PSM and when shown in combination with the other contributions of this thesis will cement WASAN as a generic PSM. The remainder of this section will introduce recursion as a systems modelling concept to be expanded in Chapter 5.

Recursion helps OR modellers to explain how complex hierarchically-interdependent units can be represented across multiple models. Typically, the relationship between recursive models is conceived as being vertical, where one model is linked to higher-level or lower-level equivalents. In these cases, we could say the lower level model is nested within the higher level model as the lower level model would have to form part of the higher level model. An example is presented in Figure 9, which shows Hoverstadt's (2008) 12 vertical levels of recursion within the Chilean Government. Each hierarchical level contains and is contained within a nested system. As the model is that of the Chilean Government, the Whole Nation is the highest level; however, if the purpose of the model were different, the model could expand to include other nations and beyond. Similarly, in Figure 9, the smallest unit is the worker, but, if required, the concept of recursion could go further and draw on biology to identify sub-systems that constitute the worker. One of the benefits of recursion is that it “allows elegant representation of organisations” (Jackson, 2003 p.87). Building a larger model without using recursion would mean the emergent properties of the individual systems would become more difficult to identify (Tejeida-padilla & Badillo-pin, 2010).

At each recursion level in Figure 9, the system is conceptualised in the same manner so the same structural/analytical rules can be applied to each level. This means that a model could be built at any level using the same modelling conventions with linkages being established across the models at different vertical levels. Beyond OR, other fields do not think of recursion as only a vertical property and use recursion in a more flexible manner to represent vertical or horizontal relationships between phenomena. In these settings, horizontal relationships refer to the analysis of continuous units on the same hierarchical plane, for example, a supply chain. This thesis will reconsider the nature of recursion in OR modelling, expanding the usual definition to include horizontal modelling of units on the same hierarchical plane.

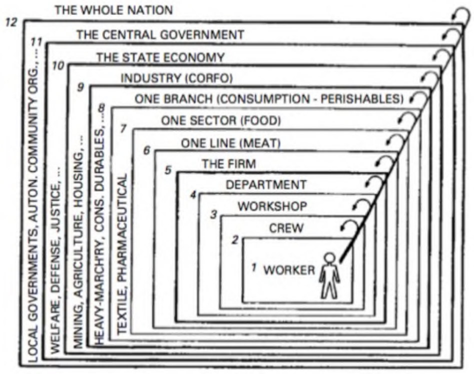

Figure 9 Twelve levels of recursion in Chile (from Hoverstadt, 2008)

OR modellers analyse situations by constructing models that represent and build knowledge on a problem (Mingers, 2003). A model is "an external and explicit representation of part of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality" (Pidd, 2009 p.10). The elements included in the model reflect what is considered important to build an understanding of the situation by the modellers (Lane & Oliva, 1998). PSMs such as SSM and SODA recognise that situations exist in a wider environment and contain sub-levels (Ackermann, 2012). This is shown in the four pillar framework through Question 2: "*Does the approach acknowledge there are systems at different hierarchical levels to the one being modelled?"* Thus, recursion may be a useful tool to formally model the higher and lower systems in this hierarchy and thereby develop an understanding of the context to ensure that model outcomes are more politically and cognitively feasible.

When examining the impact that recursion has on OR, we do not examine PSMs as they do not describe recursion being at their heart. The strongest presence of recursion is in VSM (Beer, 1981) which places recursion high in its constitution for how communication flows across functional units and between levels of systems. In VSM, recursion explains how complex systems are comprised of multiple nested subsystems that are autonomous, adaptable, self-regulatory, and self-organising (Watts, 2009). Like PSMs, VSM builds qualitative models and thus it is a more appropriate analogue through which to learn about the potential for recursion in PSMs.

In VSM, recursion is considered vertical, with the relationship between modelled systems spanning up and down the organisational hierarchy. This research project uses the concepts from recursion from VSM, but instead of only considering vertical relationships between models, it introduces horizontal recursion as a new type of recursion that is applicable to PSMs. Horizontal recursion uses the same modelling convention, but analyses other systems on the same hierarchical plane so the relationship between the analysed systems is horizontal not vertical. Thus, horizontal recursion examines systems upstream and downstream to model those using the same principles and structures. These models can be linked to move from one system model to another on the same horizontal plane and thereby model how one system can impact (and be impacted by) another. WASAN models systems that are impacted by upstream and downstream systems; therefore, to model these systems side-by-side, recursion must be used to ensure that the emergent properties of individual level systems are not lost in a meta-model.

This approach to model building creates a wider systemic understanding of the causes or impacts one unit can have on another on the same hierarchical plane. Broadening the definition of recursion to include horizontal recursion gives a new way for model builders to understand and represent the relationship between different systems and the models that reflect these.

2.8 Summary of literature review

Section 2.1 introduced PSMs and roots them within the wider development of OR. It shows how the development of OR and PSMs was pragmatic, responding the need to answer a set of practical problems by adapting and developing current theories to suit requirements. The development from existing theory to meet current needs echoes that of WASAN. Section 2.3 looked deeper at PSMs and explores them by developing the four pillar framework to assess "What are the common features of PSMs?". The answers obtained from the four pillar framework constitutes Contribution C of this thesis and will be used in Chapter 4 to answer RQ3: *"How can an approach show it has the defining features of PSMs?"* Section 2.6 introduced WASAN, the context for which it was developed, its philosophy in terms of ontology, epistemology, and axiology and how this is translated into practice through the WASAN methodology. This also introduced the notion of smart bits as the vehicle by which WASAN was developed and will be used for future development. The individual smart bits are taken from regulation, industry, and academia to fit the requirements of the context and the WASAN philosophy to waste management. Finally, Section 2.7 introduced the systems modelling concept of recursion, which shows how interdependent systems can be modelled simultaneously using the same modelling conventions. This concept is fundamental to Chapter 5 and will be explored in greater detail there.

The next chapter reviews the methodology through which the research questions will be explored.

Chapter 3

Methodology

3.0 Introduction

This chapter explains the research process undertaken in this thesis. It outlines and justifies the decisions taken during the research process, showing the coherence across the research process in answering the research questions.

3.1 The research onion

The research onion from Saunders, Lewis, & Thornhill (2012) is used to structure the chapter. The framework models the various decisions that need to be made in relation to research design, data collection, and analysis. The research onion model (Figure 10) "depicts the issues underlying the choices of data collection technique's and analysis procedures" (Saunders et al., 2012 p.126).

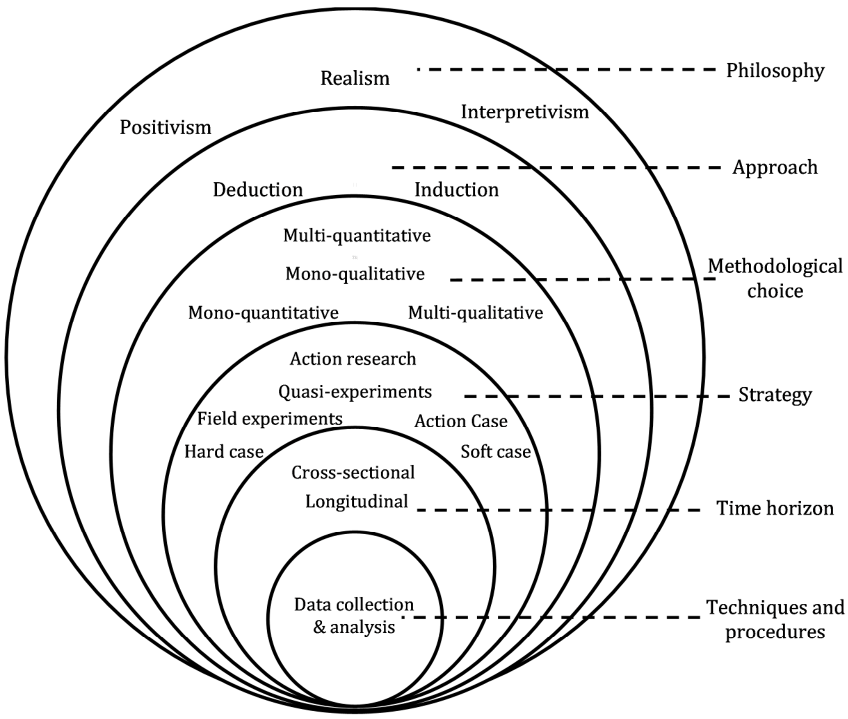

Figure 10 Research onion (adapted Saunders et al., 2012)

This chapter works through the various layers of the research onion, thereby justifying the different decisions that were made in relation to the research questions and how that informed the methodological choice.

3.2 Philosophical underpinnings

Saunders et al., (2012) write that the philosophies that underpin research relate to a set of assumptions pertaining to the development of knowledge and the nature of that knowledge. This set of assumptions is referred to as a paradigm. A paradigm is a "set of linked assumptions about the world which is shared by a community of scientists investigating the world. This set of assumptions provides a conceptual and philosophical framework for the organised study of the world." (Kuhn, 1962 p.172). These assumptions underpinning a paradigm include ontology (what is assumed to exist), epistemology (the nature of valid knowledge), and axiology (what is valued or considered right) (Iivari, Hirschheim, & Klein, 1998). Where there is an established dominant paradigm within a field, researchers make consistent assumptions regarding the nature of that world and so have a consistent set of rules in which to conduct their research. However, Kuhn (1962) suggested that natural science goes through periods of revolutions whereby normal science is increasingly challenged by anomalies that are inconsistent with the assumptions and established findings in that discipline at that time. "The growth in anomalies eventually gives way to a crisis in the discipline, which in turn occasions a revolution. The period of revolution is resolved when a new paradigm emerges as the ascendant one and new period of normal science sets in." (Bryman & Bell, 2011 p.24). For example, Newtonian mechanics dominated as the ascendant paradigm of physics from the 1700s, until Einstein's theory of relativity revolutionised this branch of science and became the pre-eminent paradigm in physics (Lee & Lings, 2008). Disciplines in which no paradigm has emerged as pre-eminent are deemed pre-paradigmic as they feature competing paradigms (Bryman, 2001). The social sciences can be categorised as pre-paradigmic with different sets of assumptions held by different researchers. This section considers the most dominant paradigms to identify the one that is most appropriate for this research project. Guba & Lincoln (1994) identified the competing paradigms of positivism, realism (or postpositivism), and interpretivism (or constructivism). This research project was conducted within an interpretivist paradigm; this is now justified by eliminating the other two paradigms and finally showing interpretivism to be the most appropriate paradigm for this project.

Positivism was rejected as the most appropriate paradigm for this research. The following section outlines the broad assumptions of positivism and justifies why it was not an appropriate choice for this research project. Positivism shows the clear progression from natural science to that of social science. A major factor in positivism is the unity of science, which maintains that the methods of natural science constitute the only legitimate methods for use in social science (Hempel, 1969). The perception of everyday scientific reality was in terms of human senses; if a phenomenon could not be seen, heard, touched, smelt, or tasted, then these phenomenon could not exist (Filstead, 1979). Positivism aims to verify, *a priori*, hypotheses most usefully stated as mathematical propositions that can be easily converted into precise mathematical formulas expressing functional relationships (Guba & Lincoln, 1994). Positivism regards the natural sciences as the model for the social science to aspire to; thus, positivism puts forth elements often associated with the natural sciences such as independent and dependant variables, mathematical propositions, quantitative data, inferential statistics, and experimental controls (Lee & Hubona, 2008). In this regard, for positivists to prove a theory, it must be observed and measured. This can only be done when you view the world in the same light as a positivist, that is, positivists see the social world as ordered rather than chaotic or random (Scott, 2002); therefore, the world can be accurately measured. To prove a theory, it must be measurable and empirically tested.

The ultimate aim in positivism is to produce theories or laws that have been empirically tested and shown to be valid and therefore 'true' (Scott, 2002). Empirical testing in a positivist manner should yield repeatable results. This makes the theory testable and, therefore, through a positivist lens the findings are more robust and rigorous. These assumptions are consistent with Campbell's (1990) view of what is good theory; empirical measurement can lead to theory that has a collection of verbal and symbolic assertions specifying the relationship among variables. Adopting a positivist view of the world is generally considered most useful when attempting to predict phenomena and produce replicable results; both of these can be useful in a research setting. However, for some research questions, positivism is not practical. For example, in organisational contexts, phenomena such as internal human processes cannot be directly observed. It is also impossible to observe causality; only association can actually be observed (Lee & Lings 2008). Hence a positivist approach would not be methodologically suitable to answer the research questions owing to the inherent difficulties in observing and inferring causality and the need to understand not only what has happened but why something has happened. It is also impossible to know through observation whether a theory is 100% accurate: "no finite number of empirical tests guarantee the truth of universal statements" (Anderson, 1983). Therefore, because of these limitations, conducting the research under a positivist paradigm would be infeasible.

The realist paradigm was rejected for this research project. Realism is associated with the quantitative OR approaches that were developed before PSMs; however, it is not appropriate to impose a realist world view on this research project which is concerned with methods associated with a different paradigm. The assumptions of realism are outlined below followed by a justification of why it is not appropriate for this research project. The realist paradigm has a broader set of assumptions relating to how research should be conducted than positivism; however, there is a great overlap between the two paradigms. Realism still views the universe as a logical and organised place run on rational and ordered principles, with emphasis on uncovering these principles through the application of rigours and strict testing of hypotheses and their being proven or disproven on the basis of empirical data (Scott, 2002). Like positivism, realism aims to gain an understanding of a problem situation by examining association and employs methodologies that mirror the natural sciences. Both share a belief that natural and social sciences can and should apply the same kinds of approach to the collection of data and to explanation and a commitment to the view that there is an external reality to which scientists direct their attention (Bryman, 2001). Like positivism, realism demands that research is empirically tested; in the realist method, a researcher should put themselves in the same state of mind as the physicist, chemist, or physiologist when he probes into a still unexplored region of the scientific domain (Durkhiem, 1982). Realism adopts an objectivist ontological viewpoint. Objectivism assumes that phenomena are ‘out there’ and separate form those involved in the construction of the phenomena (Bryman, 2001).

Whereas realism is expanded so that it may look beyond some of the constraints identified within positivism, this makes it more adept and amenable to the study of the social world. For example, positivism assumes that reality is observable, while realism relaxes this assumption and states that reality does exist but to be only imperfectly apprehendable, because of basically flawed human intellectual mechanisms (Guba & Lincoln, 1994). That is, we cannot measure everything, only infer, for example, causality. A key assumption underpinning realism is that while the verity of a general conclusion can never be proven, its falsity can (Popper, 1959). This is reflected in the manner that hypotheses are tested. Positivism aims to prove theory through measurement; realism assumes that measurement is not always possible, so to tests hypotheses through falsification, that is, aim to disprove them. If a hypothesis cannot be falsified, then, for the time being, it is considered true. This is called the hypothetico-deductive method (Lee & Lings, 2008). By conducting research in a realist paradigm, social scientists are able to explore theories that not only say what is happening but why a phenomenon is happening; this can prove much more useful to in the social world than positivism.

Realism is generally regarded as an expansion of positivism; however, interpretivism is regarded as an opposing paradigm to these two (Bryman & Bell, 2007). The following section gives an introduction to interpretivism and justifies why it complements the research questions. As identified by Kuhn, where the analytical lens of paradigm is unhelpful and inconsistent with the world, it is used to study a new paradigm that will emerge with contrasting views that are underpinned by different assumptions. Interpretivists perceive the methods of natural science as inadequate to study a social reality and instead assume that people and the physical and social artefacts that they create are fundamentally different from the physical reality examined by natural science (Lee, 1991). 'Because the world of intersubjectivity created meanings has no counterpart in the physical reality of natural science the methods of natural science are, at best, inadequate to social science. Social science therefore calls for methods that are radically different from, and foreign to those of natural science' (Schutz, 1973). Therefore, to understand the context of a situation, the world must be viewed differently from the perspective of a realist. According to the interpretive approach, "the same human action can have different meaning for different human subjects, as well as for the observing social scientist. The observing social scientist must, among other things, interpret this empirical reality in terms of what it means for the observed people" (Lee 1991, p.347). Through the interpretation of what is implied by the findings, a researcher will be able to add more context to a situation than a mathematical formula can alone. Collection and analysis of rich contextual data is likely to enable a researcher to better understand a specific problem. Interpretivism can be defined as requiring the social scientist to grasp the subjective meaning of social action (Bryman, 2001). It emphasizes the “promise of quality, depth, and richness in the research findings. It is most useful when the research question requires a ‘thick description’ where details analysis will yield valuable explanations of processes” (Marshall & Rossman, 1989 p.19). The ontological position of interpretivists is constructivism; this assumes that social properties are outcomes of the interactions between individuals (Bryman, 2001). Therefore, for the interpretivist, reality is socially constructed (Guba & Lincoln, 1994). In relation to epistemology, interpretivists see themselves as part of the knowledge-creation process; knowledge creation places emphasis on the specific time and place (Lee & Lings, 2008). To understand the issues present within a situation, the interaction between participant and researcher is relied upon; therefore, knowledge creation is subjectivist (Guba, 1990).

The key factor in deciding the most appropriate paradigm is how the analytical frame will help to or detract from answering the research questions. The analytical frame placed upon the research by the choice of paradigm should be appropriate for the research project having a high level of coherence between the paradigm and research questions being answered. Using this criteria and evaluating the possible choices as described above, it is clear that positivism is not an appropriate paradigm to conduct this research under. Therefore, this section considers the appropriateness of the competing paradigms of realism and interpretivism in answering the research questions identified in this research project. The research questions are concerned with understanding and critically analysing the defining features of PSMs. This type of research is more closely aligned with the interpretive paradigm. In addition to this, to increase coherence, it is also noteworthy that the traditional OR approaches are closely aligned with realism, while PSMs are more closely aligned with interpretivism. Therefore, it is sensible to mirror this in the research design. For these reasons, interpretivism is chosen as the paradigm to conduct this study within.

3.3 Research approach

The second layer of the research onion is the research approach. The research approach considers how theory is built. The choice here is between an inductive or deductive research approach. A deductive approach to theory-building specifies hypothesis deemed appropriate for the organisational world and tests them against hypothesis-driven data using statistical analysis (Gioia & Pitre, 1990). Bryman (2004) identifies six steps in the process of deduction shown in Figure 11.

1. Theory
   ↓
2. Hypothesis
   ↓
3. Data collection
   ↓
4. Findings
   ↓
5. Hypothesis confirmed or rejected
   ↓
6. Revision of theory

Figure 11 The process of deduction (from Bryman, 2004)

The process shown above shows how theory is used to formulate *a priori* hypotheses. These hypotheses are tested with observations (Hempel, 1966), and the findings will reject or confirm each hypothesis which leads to a revision of theory.

An inductive research approach theory is the outcome of research, that is, the process of induction involves drawing generalizable inferences from observations (Bryman & Bell, 2011). “Interpretive theory building tends to be more inductive in nature” (Gioia & Pitre, 1990 p.588), grounding theory generation in data.

An inductive approach to theory generation is often used in PSMs (for example Franco, 2013). This is because of the extent of influence the facilitator has over the participants—for example, encouraging participants to explore and confront difficult questions, offering alternative directions which were not originally on the agenda, and asking participants to clarify their own positions to ensure understanding. This interaction between participant and facilitator affect the research data. In addition, the data collection environment will have numerous uncontrolled and unknown variables; thus, an inductive approach to generating theory that can embrace the variability (as opposed to trying to control it) is more appropriate for PSM research. Therefore, this research project adopts an inductive research approach to theory generation.

3.4 Methodological choice

The third layer of the research onion developed by Saunders et al. (2012) considers the methodological choice. This considers if the research should utilise a single qualitative or quantitative approach (mono approach) or if multiple methods should be used. The aim is to have a high level of coherence within the research design (Saunders et al., 2012) so that the methodological choice fits with the research questions and philosophical underpinnings. Saunders et al. (2012) suggest interpreting the choice between qualitative and quantitative through association with the underpinning philosophical assumptions decided upon in the outer layers of the research onion. An interpretive philosophical underpinning suggests that qualitative methods are the most appropriate choice.

To validate this choice, the coherence of the central aim of the thesis and qualitative methodological choice is also considered. The central aim of the thesis is to increase understanding of the defining philosophical, theoretical, and methodological features of PSMs. In OR, quantitative approaches are reductive, that is, they express the relationships between entities in terms of mathematic formula which can be optimised or subject to quantitative analysis. Formulating relationships using reductive approaches is not associated with increasing understanding. Reductionist thinking is less appropriate for the study of complex social or real world situations (Checkland, 1981). The interdependency between the complex situations implies that attempting to break elements down into their constituent parts does not truly represent the situation; the relationships between these parts may be as critical to understanding the situation as the individual parts are (Jackson, 2000). Therefore, qualitative approaches are more appropriate as they should help to increase understanding of the phenomena being studied.

Having identified a qualitative methodological choice, we needed to identify whether mono-method or multi-method is more appropriate. Multi-methods are advocated where methods are complementary; this is being increasingly advocated in social research (Bryman, 2004) as researchers can match the strengths of one approach to the weaknesses of another (Robson, 1993) and provides scope for a richer data collection, analysis, and interpretation (Bryman, 2004). Franco & Lord (2011) and Mingers (2011) advocate the use of multi-method as the world is multi-dimensional and so using more than one method can better capture this richness and variety.

However, this study is not about generating new and novel insights into a multi-dimensional world. It is about understanding and critically evaluating the philosophical, theoretical, and methodological assumptions of PSMs. Therefore multi-methods were not required to either capture multi-dimensional insights or balance identified weaknesses within one of the methods. As such, for pragmatic reasons, the research project focused on a single method to achieve the required depth of understanding regarding the issues and assumptions present within it. Then, as is commonplace within interpretivist research, an inductive research process generalises from the specific across the body of PSMs. The theory is tested to see if it is applicable to other PSMs.

3.5 Research strategy

The fourth layer in the research onion is the research strategy; this is the plan of how a researcher will go about answering the research questions (Saunders et al., 2012). It is the methodological link between the philosophical assumptions and the choice of method to collect data (Guba & Lincoln, 2005). The research strategy provides the framework for the collection and analysis of data (Mingers, 2003). As with previous decisions regarding methodological choice and research approach, there needs to be a high level of coherence among the research strategy, philosophical underpinnings, and research questions (Saunders et al., 2012).

Braa & Vidgen (1999) identify various options for the research strategy based upon the aims of the research project. Figure 12 identifies three aims of research and how these can be achieved. Prediction is aligned with the systematic reduction approach, understanding with the interpretivist approach, and change with an interventionary approach (Braa & Vidgen, 1997).

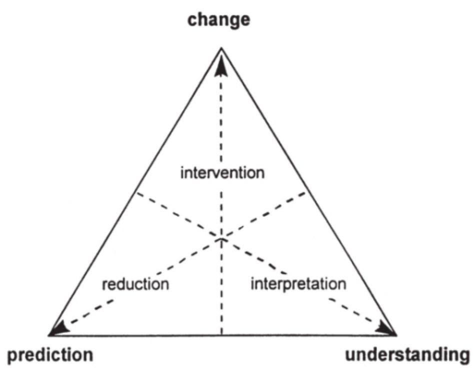

Figure 12 Research aims (adapted Braa & Vidgen, 1997)

Depending on the aim of a research project, Braa & Vidgen (1999) identify three purified research strategies: field experiments align most closely with prediction, action research focuses on change, while soft case studies aim to increase understanding. In addition to the purified research strategies, they also identify hybrid strategies: “focusing in the sides of the triangle, we can express the dilemmas (trade-offs) between pairs of ideal types of research outcome and thus focus on the hybrid methods” (Braa & Vidgen, 1999 p.33). The six different research strategies are identified in Figure 13.

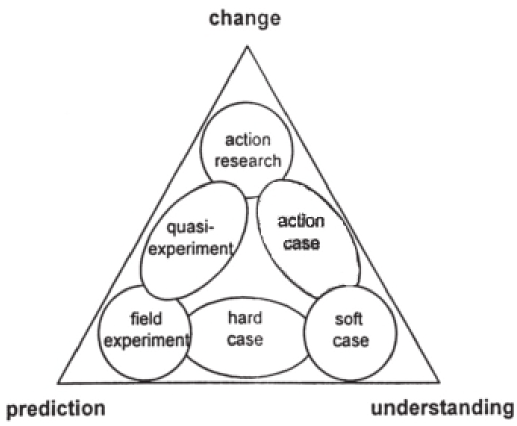

Figure 13 Six research strategies (adapted Braa & Vidgen, 1999)

This framework can help to identify the coherence between each research strategy and the research questions identified in the Introduction. This additional dimension will aid in the evaluation of the six research strategies identified in Figure 13.

Field experiments measure the effect of manipulating one variable on another variable (Robson, 1993). They usually rely on random sampling, probability theory, and statistical hypothesis testing (Fisher, 1935). This echoes the experimental method, which is the traditional approach to achieving prediction (Lee, 1991). This reductive approach reduces phenomena to mathematical expressions so it does not have coherence with the research questions or existing assumptions already identified in this project. Quasi-experiments involve an experimental approach, but unlike field experiments, random assignment to treatments and comparison groups are not used (Campbell & Stanley, 1963). In this respect, they do not meet the requirements of internal validly expected for field experiments

(Bryman, 2004). “Quasi-experiments balance change and prediction but the trade-off is made at the expense of richness of insight (understanding)” (Braa & Vidgen, 1999 p.34). Understanding the features of PSMs is critical to the success of this research project, prediction is not, therefore these two research strategies are rejected.

The hard case, is a hybrid strategy with tradeoffs made between prediction and understanding. Braa & Vidgen (1999) categorises the hard case study according to Yin (1994 p.13), who defines a case study as an empirical inquiry that ‘investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident’. Hard case studies allow reality to be captured in detail and many variables to be analyzed. The hard case is rejected because it aligns to the positivist stance (Braa & Vidgen, 1999) and therefore is not coherent with the philosophical underpinnings of this research project.

Next, this section considers the soft case study: “the case study is a research strategy which focuses on understanding the dynamics present within single settings” (Eisenhardt, 1989). Understanding of the phenomena present within the case is increased (Braa & Vidgen, 1999) as the case study is concerned with the complexities and particular nature of the case in question (Stake, 1995). The case study “involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence” (Robson, 1993 p.52). Yin (1984) identifies three types of case study: the critical case is selected to understand the circumstances under which a clearly specified hypothesis will and will not hold. For example Festinger, Riecken, & Schachter (1956), whose study focused on members of a religious cult who thought the world was about to end, wanted to understand how people react to thwarted expectations. The unique case aims to understand unique or extreme phenomena. For example, Mead (1928) believed that youth in Samoa represented a unique case, as unlike other societies youth do not suffer anxiety and stress in adolescence. This phenomenon was of course interesting in its uniqueness, as understanding these phenomena could have implications for youth across the world. The revelatory case is when researchers have an opportunity to observe and analyse phenomena that have previously been inaccessible to scientific investigation. These three types of cases are useful for understanding some phenomena; however, Bryman (2004) suggests that most case studies are selected as they provide a suitable context for the research question to be answered, and these are called exemplifying cases. Braa & Vidgen (1999) situate the soft case study as not delivering change and only focusing on increasing understanding. This implies that in a soft case study the researcher is passive, only making observations which will lead to understanding. In this research project, the researcher was not a passive observer; in-keeping with existing research into PSMs the researcher acted as a facilitator to the client (Franco & Montibeller, 2010). This resulted in the researcher contributing to a change process within the context. The next section justifies action research as the selected research strategy and explains why it was more appropriate than the soft case study.

An action case is used when a full scale action research intervention is not appropriate due to organisational constraints (Braa & Vidgen, 1999). Action research is characterised by multiple learning loops however this is not always possible, therefore action cases focus on a small scale intervention with deep contextual understanding being sought (Braa & Vidgen, 1999) typically over a single learning loop. In this project the researcher wanted to develop the methodology over several learning loops to show development and generic properties of the approach. Moreover the researcher had the access required to undertake multiple learning loops, therefore action case was rejected as the research strategy for this project.

Action research was used as the research strategy in the development of some PSMs, including Soft Systems Methodology (Checkland & Scholes, 1990). Therefore, action research was a proven methodology for the research as it is broadly accepted within the field and has proven useful in PSM research in the past. The main characteristics of action research are outlined below. It "is a cyclical process that involved formulating a definitive plan of action, fact-finding in accordance with that plan, reformulation of the plan on the bases of research results and implementing the next action plan to meet the goals of the revised plan" (Cunningham, 1976 p.217) [Figure 14]. Data is collected and fed back to the project team in a manner that aims to understand the function of the system (Heller, 1970). This data often results in a redefinition of the problem definition, which in turn demands a new action plan to be followed up, fed back, and evaluated. Therefore, action research is a cyclical process of problem definition, action planning, implementation, data feedback, and evaluation (Hult & Lennung, 1980).

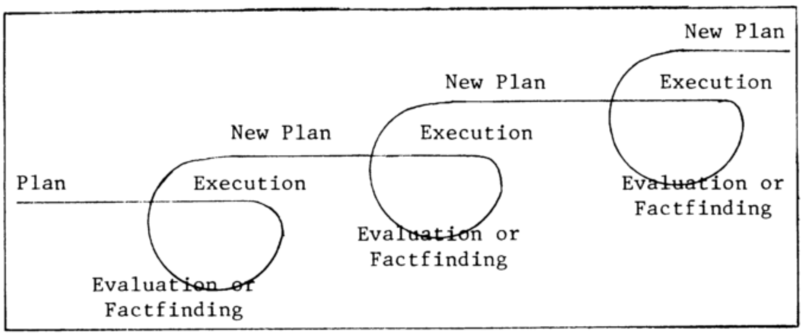

Figure 14 Action research cycle (from Cunningham, 1976)

In action research, the research process must have direct involvements in organisational change while providing an increase in knowledge (Clark, 1972). This is echoed in Braa & Vidgen (1999), which situates action research as illustrated in Figure 13. The problem under consideration should be occurring in the present and require attention (Rapoport, 1970). It is usually conducted within organisations that are seeking help in 'solving' a problem; the researchers work in partnership with the organisation to affect change in the organisation. This partnership can be described as a client-expert relationship where “the action researcher contributes methods, a pre-understanding of the problem as well as intervention skills. The client contributes his understanding of the specific situation and its idiosyncrasies” (Hult & Lennung, 1980 p.244). However, this is not always the case. Cunningham (1976), suggests action research should be conducted by people with the client system. This view has been disputed by much of the other literature surrounding action research (Hult & Lennung, 1980). The project undertaken should be beneficial and desirable for all parties involved (Foster, 1972) and should look at the situation in its totality. That is, an action researcher should not try to divorce the phenomena from the environment which gives them meaning (Hodgkinson, 1957). It is also said that as a minimum, there should be a mutually acceptable ethical framework (Hult & Lennung, 1980). Through this process, the researcher and the client organisation learn about the problem situation and the methods used to ‘solve’ this situation; overall, this process should enhance the competence of the actors involved. The learning should not be accidental but be deliberately designed to serve as a learning process (Corey, 1953). Finally, action research is primarily for understanding the change in social system; by changing these social systems (Hult & Lennung, 1980), change is explicitly part of the process. These elements are all included in Hult & Lennung's (1980 p. 247) definition of action research:

“Action research simultaneously assists in practical problem-solving and expands scientific knowledge, as well as enhances the competencies of the respective actors, being performed collaboratively in an immediate situation using data feedback in a cyclical process aiming at an increased understanding of a given social situation, primarily applicable for the understanding of change processes in social systems and undertaken within a mutually acceptable ethical framework”

Checkland & Holwell (1998 p.13) characterise action research as where "particular linked ideas F are used in a methodology M to investigate and area of interest A. Using the methodology may then teach us not only about A but also about the adequacy of F and M". This is represented in Figure 15.

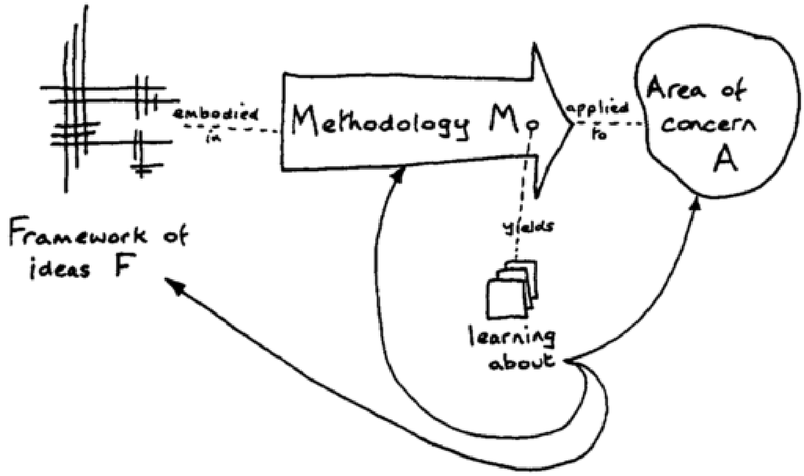

Figure 15 Action reserach - F, M & A (from Checkland & Holwell, 1998)

This research strategy has a high level of coherence with the aim of this research project. The project aims to increase our understanding of the framework of ideas which underpins PSMs. The area of concern (A) and the methodology (M) provide the test bed for learning about the framework of ideas (F). Secondary to this, the learning cycles will help to refine the methodology used and provide learning to the client system regarding the area of concern.

The research strategy of action research was selected. This decision was substantiated on the basis that action research is designed to develop knowledge of the underpinning framework of ideas (in this case the philosophy, theory, and methodology of PSMs). The cyclical nature allowed the methodology chosen to be refined and developed, and the research strategy accepts that the researcher makes change within A, which is required by the client system. Finally, action research is an accepted research strategy within the development of PSMs; for example, the action research programme at Lancaster Business School has been running for over 40 years (Checkland & Scholes, 1999).

The ethical considerations for action research are different to more traditional research strategies (Zeni, 1998). This section considers the ethical concerns of using the police force as the area of concern and WASAN as the methodology. The researcher was based within the area of concern for a period of two years, working on a knowledge transfer partnership. Therefore, access to the force was easily obtained. However, Gold (1958) identifies that when a researcher is embedded within an organisation for such a period of time, there is a chance that they 'go native'. The researcher is then unable to act as a detached observer. For this thesis, this need not be a consideration; action research with interpretivist philosophical underpinnings does not assume that the researcher is detached from the research process and, therefore, the researcher does not need to worry about 'going native'. WASAN was developed by this research's Ph.D. supervisor; therefore, there was an ethical dilemma if it is right to use it as the methodology in this research project. Here, the overriding consideration is if the methods used are appropriate for the context. In this instance, the methods were identified based on the needs of the organisation from discussions with staff about the issues they faced.

3.6 Time horizon

The fifth layer in the research onion is the time horizon; this considers if the research project will be cross-sectional or longitudinal. Longitudinal studies examine a research problem over a period of time, and the aim is usually to observe some change (Bryman, 2001). This is in contrast with cross-sectional studies that examine phenomena at a specific period in time (Bryman, 2001). The research strategy of action research aims to make change within an organisation, which alludes to this research project being longitudinal. However, the bounds of this research project did not include revisiting the organisation in the future to see how the change affected the area of concern. The changes which are revisited are with respect to the methodology. In addition, the main data collection phase only lasted a matter of months. Therefore, this research project is cross-sectional, focusing on the process of developing a methodology and enacting change in an organisation at a single period of time.

3.7 Data collection

Before discussing how data was collected in the research project, we distinguish between a unit, a system, and a model, as this will aid the description of the context and research and reduce confusion when discussing similar sounding but very different concepts. A unit exists in the real world, for example, a *Switchboard* where calls are received from the public and routed into an organisation. A system is a conceptual tool we use to think about the unit, that is, "a particular way of describing the world. It does not tell us what the world is … it may only be described as a system" (Checkland, 1983 p.671) (in our case the *Switchboard System*, abbreviated to *System*^{SB}). A model is a representation of a system using systems concepts and a coding scheme, in our case called *Switchboard Model*, or *Model*^{SB}*.* Therefore when we discuss *System*^{SB} we are referring to the *Switchboard* conceptually and not the physical entity. When we model the *Switchboard*, we are modelling *System*^{SB} as we are unable to detach the modelling conventions and systems concepts.

Action research is "not distinguished by choice of method, but rather by the way these methods are employed" (Hult & Lennung, 1980 p.245). "The concept of action research is that of simultaneously bringing about change in the project situation (the action) while learning from the process of deriving the change (the research)" (Wilson, 1990 p.2). Checkland & Holwell (1998) identify three elements that are required for action research, these are a framework of ideas, an area of concern, and a methodology which can be the manifestation of the framework into the area of concern. Therefore, this chapter identifies the three elements of framework, area of concern, and methodology that were considered before the data collection phase.

3.7.1 Selection of framework of ideas

This research is concerned with a critical analysis of the defining philosophical, theoretical and methodological features of PSMs; these elements constitute the framework of ideas that underpin PSMs. Action research is concerned with learning about a framework of ideas underpinning the methodology used within an intervention. Therefore, to critically analyse the PSM framework, the methodology chosen reflects the underpinning framework of PSMs.

3.7.2 Selection of area of concern

The selection of the organisational partner for this research project was done using theoretical sampling, that is, the case is selected as it is theoretically relevant to the study (Eisenhardt, 1989). Eisenhardt (1989) suggests that the selection of cases (or in this instance, the area of concern) must be clear and transparent. In positivist/realist research, it is more likely that an area of concern will be selected based on statistical sampling methods, as this will increase external validity. However, in interpretivist research, statistical sampling is not needed as long as the selection is transparent.

In this project, the selection was made for two reasons. First, as action research is fundamentally about change, it required the organisation to be willing to be subjected to the implantation of action (Coughlan & Coghlan, 2002). This can limit the number of organisations that are willing to participate in a research project.

Therefore, the first criterion was the ability to gain access. Second, the organisation needed to be going through some fundamental change which could be supported by the researcher. As stated in Chapter 1, the researcher was working in partnership with a UK Police Force on a KTP. The researcher was working within the *Customer Contact Department* on a project to reduce spending as a result of the cuts to police budgets in the comprehensive spending review 2010. The existing relationship between the researcher and the organisation made it easy to gain the prolonged period of access required to successfully complete the project. There was also an existing level of trust between the researcher and the organisation, which is a key success factor in action research (Eden, 1995). An introduction to the area of concern is provided below.

The area of concern is a UK Police Force that aimed to maintain service delivery despite significantly reduced government funding (Exchequer, 2010). The boundary of the project was the *Customer Contact* department which included four units. *Switchboard (SB), Call Handling (CH), Crime Desk (CD), and Crime Admin (CA). Switchboard* is based in the force control room and receives all non-emergency calls from the public; these calls are either resolved by the operator using their own knowledge of processes or procedures or routed to another unit with knowledge that will aid in the enquiry. *Switchboard* is open from 8am to midnight, seven days a week, and is staffed by eight full time equivalents (FTE). *Call Handling* is based in the force control room with a back-up centre located approximately 20 miles away. *Call Handling* receives emergency and non-emergency calls from the public, other forces, and partner agencies. They are responsible for logging all relevant information about the call on force computer systems, and assess the call's risk before deciding on a course of further action. The potential decisions are to deploy a police response as an emergency or a priority, book an appointment for an officer to meet the caller at the later date, or resolve the call without deployment (perhaps giving advice). *Call Handling* is staffed 24/7 by 52 FTE. *Crime Desk* is split across two sites across the county (north and south) and takes telephone reports of volume crime from the public; they are able to conduct low-level desk based investigations to complete crime reports but will pass any field work onto Local Investigations. *Crime Desk* is open from 7am to midnight seven days a week and is staffed by 16 FTE. *Crime Admin* is located on one two sites mirroring *Crime Desk;* they are responsible for inputting crime reports into databases, sending correspondence to victims, and managing information requests. *Crime Admin* work normal business hours from Monday to Friday and is staffed by 12 FTE. The relationship and interactions between these units are represented in Figure 16.

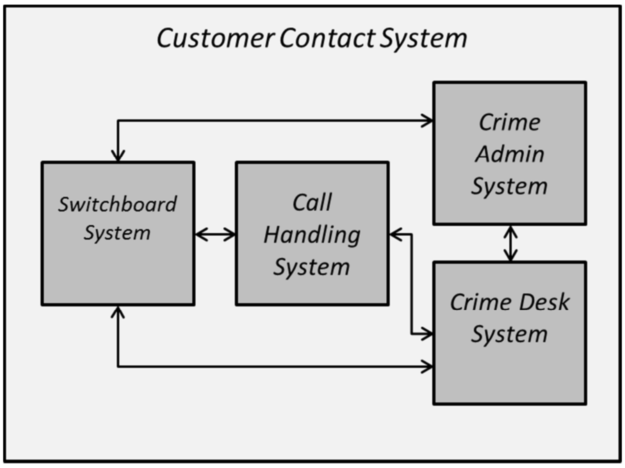

Figure 16 Customer Contact model

The Police Force had already made substantial savings in *Customer Contact* from projects, such as a simulation model to redesign shift patterns reported in Greasley & Smith (Working Paper), but due to the funding cuts needed to improve further. Until then, projects had focussed on the supply side, identifying how to better match resources to demand (Greasley, Taylor, & Smith, 2013); however, the force wanted to address the demand side of the equation. Department managers believed that analysis could identify inefficient processes and make recommendations to improve them; this would reduce demands on staff as processing time per call would reduce. Therefore, the organisation was willing to work in partnership with the researcher over a prolonged period of time and take action. The police force's aims for the project included reducing time taken to manage demand by removing 'wasted' time; reducing wasted time from units interacting unproductively with other units; involve internal stakeholders; and, build a clear transparent audit trail of decision making and recommendations.

3.7.3 Selection of methodology

The final element from FMA to be selected is that of methodology; as identified during the selection of framework, the approach chosen had to be one which was underpinned (or assumed to be underpinned) by the PSM framework of ideas. This would ensure that knowledge could be developed about the PSM framework, which would contribute to the central aim of this thesis.

Serendipity presented itself as the researcher had access to develop one of the fringe PSMs. This access provided a fringe PSM that is akin to a unique case (Yin, 1984), as there were many fewer reported uses of these approaches. These approaches were also usually in the early stages of their development, which meant that the researcher would be forced to confront the critical questions about how the approach could be used within the context. If the PSM methodology being applied in the Police Force had been an established PSM, then it is likely that these critical questions would not have been raised, which would have led to fewer learning cycles and potentially less learning about the PSM framework. Finally, the researcher decided that it was important to focus on one approach rather than trying to recruit access to multiple fringe PSMs. This enabled a much richer and deeper learning about the methodology of a fringe PSM and its underlying framework. Given the time constraints associated with a PhD, gaining access to other fringe PSMs would have reduced the depth of understanding.

The fringe PSM available, WASAN, is a qualitative fringe PSM concerned with the analysis of upstream and downstream systems to identify and reduce systemic waste. WASAN relies on facilitation to build models of the problem situation, which are analytical complex system interrelationships and involve stakeholders in bottom-up identification of process problems and improvements.

3.8 Structure of action research

The model of action research proposed by Cunningham (1976) comprises a number of learning loops (Figure 14). The learning loops begin with the formulation of a plan, which is used as the basis for fact finding in the area of concern. The researcher reflects on the plan and how it was and was not useful for enquiry into the area of concern. The plan is reformulated on the basis of these reflections and the cycle is repeated.

In this research project, the plan consisted of how WASAN would be used in the area of concern. The two Findings chapters report some of the learning loops; however, they do not identify all of them. The different learning loops in this research project are identified in Table 4. The nature or context of the learning loop is described in more detail below. The relevant learning points are discussed in detail in the Findings chapters.

The first phase consisted of the researcher's own time working within the organisation; this period of two years was akin to an ethnography (Van Maanen, 2011) where the culture of the organisation was studied along with the issues they face.

Findings from the ethnographic stage, and one of the key learning points, showed that Call Handlers felt that much of the wasted effort they put in was managing callers who they could not help; that is, the wastage was generated from an upstream system. This gave the researcher a greater understanding of the area of concern. Next, the researcher conducted a review of the PSM literature; this was to identify the key features of PSMs and increased the researcher's understanding of the framework of ideas underpinning PSMs, which would be explored in the project. The phase constituted the first learning loop, as it was the first iteration of WASAN at the UK Police Force. This is explored in greater detail in Chapter 4; however, the translation of WASAN into the context was not as predicted and as such several amendments were needed to the methodology.

Phase	Name	Participants	Description	Learning
1	Ethnographic Study	N/A	Ethnographic study to understand the culture of the police force	Increased understanding of problem situation, waste was generated upstream
2	Literature review	N/A	Review of PSMs to understand the systemic elements of methodology	Greater understanding about underpinning framework of PSMs
3	Call Handler Pilot study	6	First use of WASAN focusing on the Call Handling System	Separation of Stage A and Stage B - source of waste
4	International Case	3	Use of WASAN with Call Handlers in two police forces in Australia	Use of waste management hierarcy as keywords for Stage B1
5	Independent Review 1	N/A	Independent review of WASAN methodology with expert regulator	Intangible waste of time agreed as focus for waste reduction
6	Call Handler Case	15	Use of WASAN with Call Handlers in the UK Police Force	Data collection and analysis suitable for the context
7	Independent Review 2	N/A	Second independent review of WASAN methodology with expert regulator	Potential to analyse channels from upstream and downstream systems
8	Switchboard Case	7	Use of WASAN with Switchboard in the UK Police Force	Identified systemic nature of waste production in a meta-system
9	Crime Desk	7	Use of WASAN with Crime Desk in the UK Police Force	
10	Crime Admin	6	Use of WASAN with Crime Admin in the UK Police Force	

Table 4 Learning loops of research project

Next, the researcher had the opportunity to interview three senior officers from the emergency contact centre from two police forces in Australia. Across the two forces, only three participants were interviewed for Stages A and B. As their views were individual, it was not practical to rank them in Stage C and there was no time for a higher authority to sign off as the researcher was only at each site for a few hours, nor was there access to more senior officers. The data collected from these interviews identified that the waste management hierarchy worked as a set of keywords in Stage B1. The fifth phase was an independent review from an expert who was external to the research project. The expert was a regulator who had experience in working with and developing WASAN. The second independent review was with the same expert regulator.

Not all of the phases could be considered full learning loops as they did not take action in A using M based on the assumptions of F. However, they did all contribute to the development and learning about all three of the required elements; therefore, they are relevant to be included here. For example, the literature review did not provide action in the area of concern, but understanding the existing literature base was critical to the researchers' understanding of the framework which underpinned WASAN. The findings chapters focus on phases 3, 6, 8, 9, & 10, as they were the most interesting theoretically. They also most closely resembled the learning loops identified by Cunningham (1976)

Next, the chapter identifies how data was collected to build the WASAN models and aid the critical analysis of the defining philosophical, theoretical, and methodological features of PSMs.

3.9 Data collection methods

Section 3.4 identified that qualitative data collection techniques were most appropriate for this project. Ryan (2006) writes that the manner in which data is collected reflects the beliefs about knowledge and human experience adopted by the research. Data collection methods are not simply neutral procedures but carry assumptions intrinsically linked to the paradigm level of assumptions of the research. "The action research procedure required the use of participative methods for data collection, analysis and diagnosis." (Hult & Lennung, 1980 p.244). Therefore the methods used should allow for interaction and knowledge building between the researcher and participants. This has a high level of coherence with interpretivism, which assumes that reality is socially constructed and, therefore, decision making is a reflection of these social constructions (Franco & Rouwette, 2011). Therefore, to aid this decision making, research should seek to understand participant perceptions and see how they perceive the issues being raised.

The research project employed two main data collection methods—interviews and focus groups. Miller & Brewer (2003) identify that interviews provide the most in-depth method of studying perceptions, thereby allowing the researcher to probe for more detail from the respondent and obtain clarification. Seeking clarification is not possible in approaches where the researcher is not present with the respondent. Focus groups can leverage a group dynamic to identify and build upon new concepts. "The hallmark of focus groups is the explicit use of the group interaction to produce data and insights that would be less accessible without the interaction found in a group." (Morgan, 1988 p.12). The stages in which these two data collection methods were employed in the research project was one of the many learning points discussed in Findings 1, therefore it will not be discussed here. However, where each method was used is identified in *Table 5*.

Robson (1993) identifies three types of interview: fully structured, which asks a predetermined set of questions with responses recorded on a standardised schedule; semi-structured, where the interviewer has a set of questions in advance, but is free to modify their order and content based on their perceptions of what is most appropriate; and, unstructured, where the interview is completely informal, and the interviewer has a general area of interest and concern, but lets the conversation develop within this area. This project selected semi-structured interviews; since each stage of WASAN has a clear set of aims and goals which should be achieved, the semi-structured interview functioned like a ‘shopping list’ (Robson, 1993) with the researcher having a number of topics which need to be covered, but the exact working of questions and time dedicated to each task varied based upon the interview situation. This afforded the researcher much more flexibility than a structured interview, which would have been too rigid for these purposes.

Unstructured interviews would not have been appropriate either; to guide participants around the WASAN methodology the interview needed to be a respondent interview, where the agenda and opportunity to probe is available to the interviewer (Powney & Watts, 1987). Each type of session had a clear goal or output, as shown in *Table 5*; the researcher used a basic set of questions developed through the action research project to achieve the objectives in each stage. This objective was usually to build or collect the data to develop a model which could be interpreted by the participant(s). The model structured the participant's thoughts regarding the topic under consideration.

Stage	Objectives	Data Collection Method
A: Define System Boundary	To create a written definition/purpose for the system in focus. The definition should identify all tasks staff working in the function should be doing. The Stage A interview is also a chance to discuss appropriate times for data collection.	Interview
B: Analyse Internal & External Operations	To identify a range of avoidable wastes within the system. Once wastes are identified, use the keyword analysis or sensitivity analysis to find ways to reduce the impact of these wastes.	Interview
C: Evaluate Actions	To identify candidate actions which are a high, medium, and low priority for the system in focus; these are to be identified using the action evaluation grid.	Focus Group
D: Programme Deliverables	To seek sign off on the actions from a higher authority.	Interview/Focus Group

Table 5 Output and data collection method for each WASAN stage

Focus groups have more than one participant who collectively make sense of phenomena (Bryman, 2004). The role of the researcher is to act as a facilitator to move the group along (Rubin & Rubin, 2012). Typically, focus groups can explore an issue in more depth as participants challenge each other's views (Bryman, 2004). However, there are some noted disadvantages of focus groups. Bryman (2004) suggests that with focus groups, researchers have less control, the data can be difficult to analyse, difficult to organise, a few individuals can dominate the session, views expressed may be those which meet cultural expectations, and, there is the potential to cause discomfort among participants. Additionally (Patton, 2002), identifies that the researcher cannot guarantee confidentiality. In this project, these disadvantages were overcome or mitigated against; each one is discussed below. The researcher set out a clear structure at the beginning of each session (discussed in Chapters 4 and 5), which the group adhered to. This ensured that the researcher maintained adequate control of the session. The output from the group was a model representing the group's views on the issue of concern; this constituted the main analytical output and therefore the researcher was not overwhelmed with data. The focus groups were organised as an internal meeting and, therefore, the researcher was able to utilize their position as working within the organisation to schedule the meetings. To minimise a few people dominating the meeting, the researcher ensured that all participants had a chance to agree or disagree with each point identified in the model; however, the researcher recognised that not all views were equal. One of the main benefits from the focus group was to get 'buy in' from the powerful stakeholders (Eden, 1992); therefore, the most senior manager in the room was given control of recording the outputs. This session represented a phase of convergent thinking; therefore, the group was encouraged to identify the commonality in participants views (Franco & Lord, 2011). They should seek accommodations (Checkland & Poulter, 2010) each other and thus more culturally accepted views would help guide this process. It was unlikely that any participant would feel discomfort from the process; all participants worked for the police force and so were a known to each other (Bryman, 2004). At the beginning of the session, participants were asked to respect the views of others and to consider that options being discussed could have been raised by others in the room and so to remain respectful. Finally, with respect to confidentiality, all participants were told at the beginning of the session that the researcher could not guarantee confidentiality from that specific process, but it would be appreciated if all participants respected the confidentiality of others in the room; informed consent forms were also amended to reflect the change in conditions.

As this thesis makes interpretivist assumptions regarding the nature of research, it is possible that researchers will put their own slant on the participants views, which is likely to affect what is learnt (Rubin & Rubin, 2012). Therefore, to increase internal validity, a process of respondent validation was followed for each participant. Respondent validation is a process where participants are provided an account of the researcher's findings with the aim to seek corroboration of the account that the researchers has arrived at (Bryman, 2004). In PSMs, the model can act as an audit trail and a record of an interview or focus group. The model is built with the participants and should be representative of their view. It is possible to validate the model with participants as the model is built (Franco & Lord, 2011; Shaw, 2006). In this study, participants were either asked to review the model at the end of the meeting or were sent a list of the points that they raised, which they wanted to be included in the model. At this point, the participant reflected upon their contributions and was given the option to add further pertinent points or retract statements they were uncomfortable with. In addition to this, where individual level models were aggregated into group models, theming was validated by a member of staff who had knowledge of the system; this ensured sensible theming of the participants' constructs.

It was key to ensure the language used during the interviews was free of jargon which could be misinterpreted by participants. Fortunately the structure of the interview's allowed the interviewer to clarify meaning if required. As the researcher had been embedded within the organisation already they were aware of the terminology used in the police force and were able to adapt the interview accordingly. If the researcher was implementing WASAN in a different police force or other emergency environment it is recognised that the same terminology could have different meaning, and therefore the researcher would have to ensure the language used in the new context was interpreted in the way it was intended.

The same stages of data collection and analysis (A-D) were conducted on each of the four units; this resulted in comparable models being built across all four systems. The nature of the data collected for each unit is specified below.

3.9.1 Data collected

For two years, the researcher was embedded within the Police Force, providing analytical support to reduce expenditure within *Customer Contact*. Rich understanding of the problem context and culture were built through two years of daily observations, akin to ethnography (Van Maanen, 2011). At the end of Year 2, WASAN's Stages A–D were used to build a model of each unit with data collected from individual interviews and focus groups. In total, 40 respondents informed the model development across 4 units and approximately 2198 minutes of interviews [Table 6]. For all interviews, the researcher wore a suit, tie, and jumper; the police is a formal setting and so it was appropriate to wear a full suit like other members of staff who are not provided uniforms. The jumper sought to dress down the outfit to help respondents feel more at ease. All participants were interviewed at their place of work; this reduced abstraction time where the member of staff had to be away from their regular duties. They were also able to return to work on short notice if needed; this happened once during the interviews where the Control Room Inspector had to manage an incident. Conducting the interviews at the participants' place of work also gave the researcher an opportunity to see the participants in their natural setting, as advocated by Benbasat, David, & Mead (1987), which is key to widen their contextual understanding of the situation. Where possible, interviews were recorded using a digital audio recorder, and this enabled a complete transcribed record of what was said for subsequent analysis (Rubin & Rubin, 2012). These audio notes served as a back-up to the model built and validated in real time. Three participants across all four units refused to be recorded and did not state their reasons for this.

The aggregated data collection across all units is shown below in Table 6. The table shows how the *Call Handling Pilot* took longer per interview than the other interviews. This would partially be because the interviews included both Stages A and B. The researcher was still refining their own craft skills (Ackermann, 1996) and learning about the methodology. As a result of reflections on the pilot study, the interview schedule and structure was reformulated and a new plan for action was created in the *Call Handing* study. *Call Handling* as the first unit modelled using the new interview schedule and structure had a larger number of interviewees in Stage B and more participants in Stage C. This is because it was the largest system and also the earliest learning loop using the schedule and structure; both these factors meant that it took longer to reach theoretical saturation.

Unit	Unique Participants	WASAN Stage	Data Collection Method	Number of Participants	Total Time (minutes)
Switchboard	7	A	Interview	1	27
		B	Interviews	5	190
		C	Focus Group	4	41
		D	Focus Group	2	30
Call Handling Pilot	6	A	Interview	6	576
		B	Interview	6	
Call Handling	15	A	Interview	1	37
		B	Interviews	11	638
		C	Focus Group	6	90
		D	Focus Group	2	60
Crime Desk	6	A	Interview	1	7
		B	Interviews	4	224
		C	Focus Group	4	41
		D	Interview	1	30
Crime Admin	6	A	Interview	1	8
		B	Interviews	4	140
		C	Focus Group	3	29
		D	Interview	1	30
Total	40	Total			2198

Table 6 Aggregated data collection

3.10 Data analysis methods

The data analysis methods needed to be coherent with the choices made at earlier stages of the research onion (Saunders et al., 2012). Action research aims to simultaneously assist in practical problem-solving, while expanding scientific knowledge (Rapoport, 1970). However, the same analysis and data is not necessarily of interest to all parties. This project distinguishes between the learning and analysis that took place in relation to the area of concern (UK Police Force) and the methodology (WASAN) and framework of ideas (learning about the theory of PSMs). Each of these components was analysed in a different manner and had a different emphasis at different points of the project; these different types of analysis are discussed below.

3.10.1 Analysis of the area of concern

Action research is a collaboration between the researcher who brings expert knowledge and the organisation that brings contextual knowledge. This partnership must be mutually desirable (Foster, 1972) and therefore the organisational partner must derive some benefit, that is, learning from the analysis of their context. The WASAN analytical methodology aimed to identify recommendations which could be used by the police force to reduce wasted time in the analysed unit. The WASAN process of analysis is described in Chapter 4.

This data analysis was carried out throughout the data collection phase. Much of the modelling took place in real time (Ackermann & Eden, 2001) and the model was built with the participants face-to-face. The outputs and recommendations for the project were written up into a final report. This created the impetus for immediate action (Hult & Lennung, 1980) for the police force, thereby implying that they could implement actions at their discretion.

3.10.2 Analysis of the methodology

The WASAN methodology was limited in the area of concern at the beginning of the project. The approach was context-specific and built for the nuclear industry (Shaw & Blundell, 2010), consequently, it was not suitably generic to be successfully implemented at the police force without development. The process of development was subject to analysis using action research. Learning in action research "requires intellectual reflection on the experience and that in turn requires the establishment of concepts so that 'what has been learned' can be known and made explicit" (Wilson, 1990 p.3). Drawing from Cunningham (1976), this project used learning loops where a plan was created; this plan is put in action and then reformulated based upon reflections. The plan was how WASAN would be operationalised in the unit of analysis. After each intervention, the researcher reflected critically on the how the relative success or failure of how the plan translated into reality. Where elements did not work as intended, the researcher revisited interview recordings, notes, and original literature to understand why. During the *Call Handling* Pilot Study three participants were interviewed to understand how useful they found the WASAN process to diagnose which elements required further development. Based on these reflections and investigations, the plan of how WASAN was to be used was updated (reformulated) and a new learning loop was started. This analysis needed to take place as the project was progressing. At each phase, new learning was identified and implemented in accordance with the traditions of action research. In this manner, the development of the WASAN approach led to a greater understanding of the methodology. However, the central aim of this thesis was to critically analyse the underpinning philosophical, theoretical, and methodological features of PSMs. These are encapsulated in the framework of ideas and the analysis of this is considered next.

3.10.3 Analysis of the framework of ideas

Analysis of the underpinning framework of ideas was central to the answering of these research questions. The analysis for each of these questions (which in some part relates to the framework of ideas for PSMs) is discussed below and discussed in relation to the established literature in the discussion chapter.

The answer to RQ1 has already been considered in the Literature Review and so is not considered here. RQ2 is *"How can PSMs be developed into suitably generic approaches applicable in multiple problem contexts?".* To answer this question, the project made a comparison between the elements which has been changed from the original context and those which remained the same. Comparing the two different types of elements enabled identification of similarities and differences between the two categories. These were explored in relation to WASAN and the implications of this for the approach.

RQ3 asks *"How can an approach show it has the defining features of PSMs?".* To answer this question, the project revisited the data from the study through the lens of the 15 questions in the four pillar framework. Using examples from the study, the 15 questions were worked through systematically to ensure that all elements were identified.

RQ4 is "Can philosophical, theoretical and methodological contributions identified in one PSM be shown as relevant in others, thus showing a common framework?". To answer this question, the project explored the notion of the expanded system. After the analysis of the individual system was completed, further analysis was conducted to identify how to reduce waste across the network of the four modelled systems. That is, individual units could affect the performance and compromised other units' performance; thus, further analysis at this higher level was required to understand this and provide a broader range of options to the police force. As the main focus for analysis, the four individual units occupy recursion Level 1 (using Jackson's (2003) classification); thus, *Customer Contact* occupies Level 0 and individual staff within each Level 1 unit occupy Level 2. Constructing four separate Level 1 models would fail to identify the systemic complexity arising from their mutual reliance. Building a single Level 0 *Customer Contact* model would include elements that are irrelevant to our project and potentially cloud issues. Thus, the integrity of the four individual models had to be protected (to understand each unit) whilst building models that could be combined (to understand the interactions between units).

The data was re-examined to identify any comments on interactions between the four individually modelled units. Any information which was not relevant within the model boundary but was argued by the participant to influence (or be influenced by) other units using other models was recorded. For example, *Call Handling* identified *Switchboard* as a source of waste when they receive 'incorrect calls from Switchboard'. Thus, instead of only considering the information within *Call Handling* the model also considers it at *Switchboard*. To identify the relevance of this to the underpinning framework of PSMs, examples of similar model building approaches were sought from the literature.

3.12 Summary of Methodology

This chapter has justified the decisions taken throughout the research process; a high level of coherence across all decisions was ensured by considering each layer of the research onion (Saunders et al., 2012) and recognising the interdependence at each layer based on the decisions already taken and the research questions. These different decisions are depicted in Figure 17.

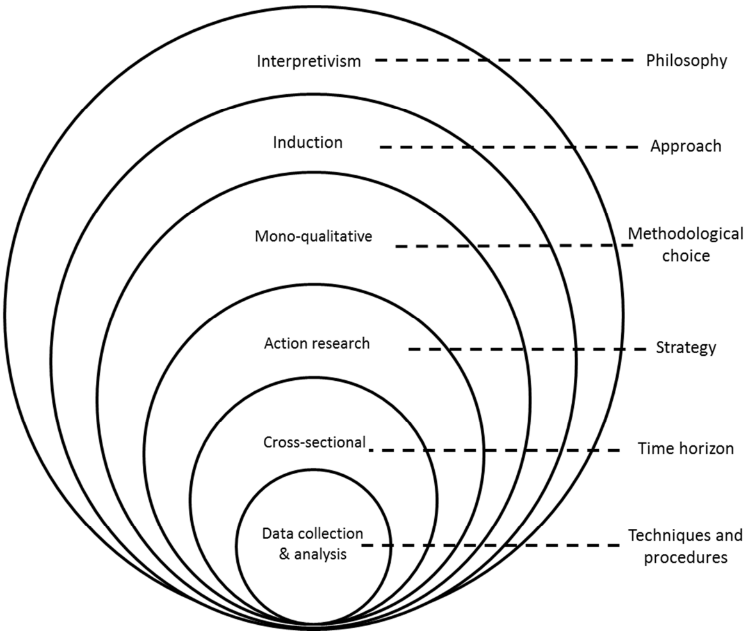

Figure 17 Research onion showing methodological choices

The research was conducted within an interpretive paradigm, thereby generating theory through induction. The research strategy chosen is the action research approach, which means the project will simultaneously generate learning about the area of concern, the methodology used, and the framework of ideas underpinning that methodology. The area of concern selected was a UK Police Force who the researcher had been working with for a period of almost two years. Analysis of the police force was carried out using WASAN; both the methodology and the area of concern were vehicles to understand more about the underpinning framework of ideas for PSMs. Qualitative data was collected through interviews and focus groups, and the analysis of this data provided information about the area of concern, the methodology, and the framework of ideas.

Chapter 4

Findings 1: Development of the WASAN methodology

4.0 Introduction

This project aims to provide a critical analysis of the philosophy, theory, and methodology of PSMs. To achieve this aim, this chapter is concerned with how qualitative OR approaches can be developed and how the common features of PSMs can be identified in newly developed approaches.

4.1 Structure of chapter

First, this chapter presents a study showing the findings from the analysis of the application of WASAN within a new context at a UK Police Force. The study provides the context required for the project to answer RQ2 and RQ3:

RQ2 "How can WASAN be developed to be suitably generic that it is applicable in multiple problem contexts?"

RQ3 "How can an approach show it has the defining features of PSMs?"

Second, the chapter addresses questions on the generic applicability of WASAN. This shows the theoretical, practical, and methodological development required of an approach for it to be applicable in multiple problem contexts. Drawing from the study, the project shows how smart bits were developed to make WASAN generic and applicable across multiple contexts. Third, this chapter considers WASAN in relation to the four pillar framework developed in Chapter 2. Comparing WASAN with the 15 questions from the four pillar framework aims to assess if WASAN shares the common features and a common philosophy with the existing PSMs. This provides two outcomes. The first is in relation to the operationalisation of the four pillar framework; one of the major problems with existing definitions of PSMs is that they are not useful in discerning whether an approach is or is not a PSM. The lack of a method to operationalise these definitions implies that they cannot be used to identify if fringe PSMs have a case for inclusion as a bonafide PSM. Second, showing the commonality of WASAN and the existing PSMs identifies the extent to which WASAN can inform the philosophy, theory, and methodology of the existing PSMs. If WASAN shares all the common features of PSMs, then research into WASAN and its philosophy should be transferable to the existing PSMs.

The study presented in this chapter considers the application of WASAN in the *Call Handling* function of the UK Police Force. WASAN was also deployed in three other functions at the force: the *Switchboard*, *Crime Admin*, and *Crime Desk*; however, for brevity, the detailed presentation of these studies have been omitted from this chapter as the same analytical process used in *Call Handling* was followed in the three further functions. The presentation of these three further applications of WASAN and the findings identified from analysis across the four studies will be communicated in Chapter 5. This will allow these studies to be presented using a different analytical frame to highlight other learning objectives identified in this project. The *Call Handling* function was selected to be described in detail in this chapter, because it is the largest of the four studies; thus, there is a richer vein of data to draw from and make comparisons with for the application of the four pillar framework. Further, *Call Handling* was the first application of WASAN in the Police Force and, as a result, the approach underwent a more extensive development and the researcher a steeper learning curve during the application in *Call Handling* than it did in *Switchboard*, *Crime Admin*, and *Crime Desk*. In the three further studies, the WASAN methodology remained largely unchanged.

4.2 The use of WASAN in a UK Police Force

WASAN was deployed in *Call Handling* in two phases. First, a pilot study was conducted to test whether concepts from the original approach were transferable to the new *Call Handling* context. After revisions to WASAN, which made the approach applicable for *Call Handling*, the full-scale Call Handling study took place. In the pilot study, only Stages A and B were deployed, because the main changes to how WASAN would be operationalised only effected Stages A and B. In the full Call Handling study, Stages A–D of WASAN were deployed. These four stages are shown in Figure 18 and consist of the following aspects:

A. Define system boundary: Agree the scope of analysis e.g. the process, wastes.
B. Analyse operations: Encourage divergent thinking to identify concerning issues and candidate solutions through:
    1. Analysing internal operations by exploring waste production inside the unit.
    2. Analysing external operations by exploring the impact of up/downstream processes on waste production in a unit.
C. Evaluate actions: Encourage convergent thinking to narrow, evaluate and select candidate actions to implement.
D. Program deliverables: Consider candidate actions in the wider work plan and agree actions to implement.

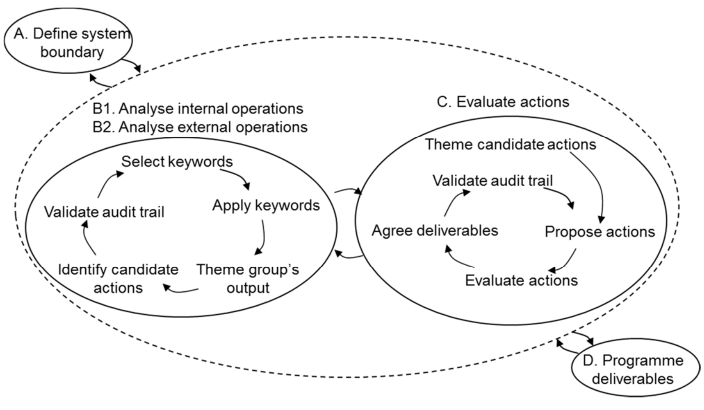

Figure 18 WASAN stages (from Shaw & Blundell, 2010)

The following sections first describe the methodology applied in the *Call Handling* pilot study (Stages A & B) followed by a description of the full *Call Handling* study (Stages A–D).

4.2.1 Call Handling pilot study

Prior to commencing the larger scale deployment of WASAN in *Call Handling*, a small-scale pilot study was used to identify what adjustments needed to be made to WASAN from the original approach, as used in the original nuclear context, before it could be deployed in *Call Handling*. During the planning of the pilot study, four areas of concern were identified where it was unclear how a specific element of WASAN would translate into *Call Handling*. These four areas of concern were turned into pilot questions (PQ) on the use of Stages A and B of WASAN within *Call Handling;* thus, answering these questions was the specific aim of the pilot study, and the four questions are given below:

PQ1. How can WASAN be operationalised in a *Call Handling* environment?

PQ2. How does the notion of avoidable waste (as taken from nuclear) translate into the *Call Handling* context?

PQ3. What are the important elements required in a systems definition?

PQ4. What keywords are best to ensure that participants are able to generate sensible actions in Stage B?

These questions were identified by the researcher when planning the pilot as key uncertainties.

To answer these questions, six participants from different areas surrounding *Call Handling* were interviewed as part of the pilot study; their roles are shown in Table 7.

Job Title	*No. Interviewed*
Customer Contact Manager	1
Control Room Inspector	1
Call Handler	3
Quality Assurance Officer	1

Table 7 Number of participants in the Call Handling Pilot Study

To answer PQ1, we consider the two potential methods of operationalising WASAN (that is, interviews and focus groups). Data could be collected from all the participants during one single focus group or individuals could participate in one-on-one interviews with data aggregated at the end. In the original use at a nuclear facility, all participants shared information during one facilitated session to build a WASAN model in a single focus group. However, at the Police Force it would not be practical to operationalise WASAN in this manner, as simultaneously excluding large numbers of staff from their regular duties would affect the ability of Call Handlers to respond to incoming calls and it would exclude staff who were not on shift during the focus group. Therefore, the researcher interviewed people individually. This had the advantage of being able to involve a range of interviewees from across all the five shifts and without causing major disruption to the *Call Handling* system. This first development to WASAN meant that the output from each interview had to be collated at the end of each stage. Collating the data from individual interviews and analysing it as a single data set is common practice in some PSMs. For example, in SODA, individual cognitive maps can be created during one-on-one interviews, which are then combined with other individual maps into a single composite strategic map representing the views of the individual participants (Eden & Ackermann, 1998). The pilot study provided an opportunity to test if and how data from individual interviews could be combined and successfully analysed.

PQ2 is concerned with defining the waste to be reduced. In the Pilot Study, participants were responsible for defining the wastes to be considered. They were asked to think about sources of waste, and these were things which would increase the overall cost of running the system. Examples of these wastes from the Pilot Study include *'Overtime spend', 'Duties not matching demand', Ineffective technology', 'Other agencies incorrectly referring to the Police', and 'Too long on calls'*. Conceptually identifying these wastes was a struggle for participants as the effects of these tangible wastes on the system was limited and very narrow in focus. Hence, a learning point here was that WASAN needed to provide informed guidance about the nature of waste for the approach to be successful within *Call Handling*. To answer this question, the researcher had to reflect critically on the results of the *Call Handling* pilot study.

To answer PQ3 in Stage A, interviewees were asked to identify the purpose and boundary of the *Call Handling* system. This process of establishing the boundary was structured by the facilitator, who asked participants to identify the following system properties:

- Inputs—the system users. These included 'Public', 'Other forces', and 'Partner agencies'.
- Outputs—the outcomes from using the system. These included 'Police attend within one hour', 'Police attend as an emergency', 'Advice', 'Police appointment', 'Neighbourhood Police Officer attend', and 'Referral to other agency'.
- Channels In—the ways in which the inputs entered into the *Call Handling* system. These included *'Phone', 'Email',* and *'Text to talk'.*
- Channels Out—the ways in which the outputs exit the *Call Handling* system. These included *'Phone'* and 'E*mail'.*

All of these elements were captured during the interview to build a model that functioned as a visual representation using a tabular format (Shown in Figure 19).

The final element needed to answer PQ3 was to gain an understanding of how to define the purpose of the *Call Handling* system. For this, interviewees' definitions were structured using the smart bit CATWOE from SSM (Checkland & Scholes, 1990). Participants were asked to think about the Customers, Actors, Transformation, Worldview, Owners, and Environment that define the *Call Handling* unit. The researcher (acting as a facilitator to the interviewee) made notes which formed the written definition of the *Call Handling system*. The model was validated by each interviewee as it was built; it acted as the record and audit trail of the interview and helped the participant to focus on the system which they were analysing during Stage B. Figure 19 is the output from a single Stage A interview from the Pilot Study.

Inputs	Channels In	Platform	Channels Out	Output
Public who live in [redacted]	Phone	**Control Room**	Phone	Police Attendance within an Hour
Public who travel through or visit [redacted]	Email		Radio	Police Attendance Police attendance Emergency
Public who work in [redacted]	Text to Talk		Email	Advice
Partner Agencies	Letter	*The control room received calls from the public and [redacted] partners and processed the information from these calls. Where appropriate it will give advise or pass the contact onto the most appropriate external partner to give that advice. The calls will be risk assessed and graded for a response, depending on this grading an appropriate resource will be allocated and dispatched within the nationally agreed time scales as managed by the control room inspector. the contact will be recorded along with the officers attendance and assessment, information is passed on to internal departments that require that information*		Police Attendance
Other Police Forces				Police Attendance Neighbourhood officer
				Referral to another agency
				Referred to other force

Figure 19 Definition of Force Control Room by participant in the Call Handling Pilot Study

PQ4 is concerned with Stage B and the keywords used to analyse the systems operations. The aim here was to understand how and if a keyword analysis would work in *Call Handling*. In the first three interviews, the keywords used by participants were self-generated. This was unlike the previous example in nuclear, where external keywords were taken from the WMH. Across the three interviews, participants identified nine keywords for the Police— *'Better filtering of calls', 'Getting all useful information from the job', 'Wrong calls', 'Avoid calls', 'Quicker management of calls', 'Reduce the number of unnecessary call backs', 'Reduce the length of calls', 'Efficiency through knowledge'* and *'New channels'*. These keywords did not seem as effective as those used in nuclear, and some participants struggled to identify any appropriate keywords to use in the subsequent analysis. This disengaged some of the participants and reduced their effectiveness, as they seemingly withdrew from the process. Reflecting on these first three interviews, the researcher decided to trial the WMH as keywords in *Call Handling* to see if they would work. This would speed up the process and if successful lead to higher levels of engagement from participants during the main divergent thinking phase of the WASAN approach. Figure 20 depicts an extract of a keyword analysis by a participant who used keywords from the WMH to structure the analysis. In Figure 20, the keyword analysis was focussed on people calling into *Call Handling*, aiming to reduce the two avoidable wastes identified in the first column. The five keywords from the WMH are shown in the top row. Using the grid as a guide, participants generated actions for each waste using the keywords as prompts. All actions were recorded in the grid square corresponding to the waste\keyword. Where more than one action was generated for a waste\keyword, the action is separated by ';;;'. During the second three interviews, participants were able to identify actions for 'Avoid' and 'Minimise'. However, interviewees struggled with identifying actions to 'Recycle', 'Recover', or 'Dispose' the avoidable wastes. Conceptualizing what 'recycling overtime spend' even meant proved too difficult for many; therefore, 'Recycling', 'Recover', or 'Dispose' were not an effective prompt for participants. The participant from Figure 20 spent more time thinking about the meaning of the keyword in practice than thinking about actions as a result of the prompt. Furthermore, the two actions that were generated by the keywords 'Recycle' and 'Recover' did not really fit with the keywords they were prompted by.

	Avoid	Minimise	Recycle	Recover	Dispose
Overtime Spend	Pull resources from across teams if under minimum staffing (IR can pull from LI if IR is under staffed for shift) ;;; Change in employment contract, to give time back and overtime ;;; Increase zero hour contracts ;;;	Increase threshold of minimum staffing above the required minimum to account for anticipated sickness ;;; proactive management of staff, ensure big events are resourced before an increase in OT payment is required ;;;			
Duties don't match demand		Understand demand and plan duties according to this ;;; Working from home - increase workforce mobilisation ;;;	Better capture of variables that influence demand and how this affects demand ;;;	Understanding how other forces manage demand ;;;	

Figure 20 Keyword analysis by participant using WMH in Call Handling Pilot

4.2.3 Findings from the pilot study

After the pilot study, the researcher reflected critically upon his own observations, notes, recordings, and comments from the participants about WASAN to answer the four questions posed at the beginning of the pilot study. The reflections focused on how the researcher perceived elements would work and how they actually worked. Where events did not line up with the plan or new obstacles not identified in the plan were identified, a new plan was sought. Based on these reflections and process of planning, the approach was developed to fit better with the *Call Handling* context. The answers to these questions and the developments made (the new elements to the plan) are detailed below.

PQ1 was how to operationalise WASAN in the Police context? In particular, the questions entails understanding if the proposed change to individual interviews from group sessions would work. The individual interviews in Stages A and B worked to elicit the required data on the system. Participants were able to generate sensible actions to reduce the impact of waste on the *Call Handling system* through facilitation. The one-on-one interviews were scheduled for times when demand was typically lower and staff levels typically higher (as lunch breaks were avoided). Having collected individual level data, the aim is to combine the models into a single composite model of the situation, as is common practice when using SODA (Eden &

Ackermann, 1998). For individual models to be combined, each model would have to be commensurate with one another; that is, they all analyse the same system, looking at the same wastes, and use the same analysis. Unfortunately, in the pilot, each individual model took a slightly different approach and therefore building the results into a single composite model was inadvisable. For example, the system definition in Stage A was decided by the individual leading to slight differences in the system model being analysed by each participant. There were differences in the type of wastes analysed, the keywords used, and the defined purpose of the system. To ensure that the models were commensurate, issues relating to these areas needed to be clarified to ensure consistency. Consistency across models would allow them to be combined, compared, and analysed alongside each other. Answering the remaining three questions about the system boundary, avoidable waste, and keywords were key to successful operationalisation of WASAN within the UK Police Force.

PQ2 was how the notion of avoidable waste, taken from nuclear, would translate into the Call Handling context? In nuclear, the avoidable waste being analysed was specified in the brief; participants were given a clear aim. In the Call Handling Pilot Study, the aim was much broader and lacked the specificity of nuclear. Participants were not told what the avoidable waste was; only that the objective was to identify ways in which to reduce the overall cost of running *Call Handling* by reducing waste. They were to identify the waste themselves during Stage A. As participants identified their own wastes and defined their own system, the individual models analysed different wastes; this resulted in individual models that were not commensurate with one another. There was no value in combining models that were reducing different wastes. Each model was customised to its own specific individually constructed context; it was not possible to reconcile the differences between these individual models. To address this issue, the researcher had a workshop with the two previous developers of WASAN. In the workshop, the researcher presented the results from the *Call Handling Pilot Study* and highlighted the challenge of defining waste in *Call Handling* and the implications of it for data analysis. Through considered discussions, the workshop decided that participants should be told what the waste was that they were aiming to reduce and thereby ensure that (a) all participants had the same focus and (b) models could be combined and analysed at the aggregated composite level. To identify the most appropriate waste to be considered in *Call Handling*, the researcher drew on previous uses of WASAN in nuclear to understand what could be considered an avoidable waste. Instead of providing useful analogues to transfer over to the new context, examining the nuclear applications of WASAN only constrained the researcher's thinking to tangible wastes, for example, the plastic bags in (Shaw & Blundell, 2014). Examining tangible wastes proved unhelpful and irrelevant to the *Call Handling* context; therefore, the researcher began to focus on the actual operations of *Call Handling* to identify the waste. Internal and external Police documentation was reviewed, including internal role profiles for Call Handlers, operating procedures, and National Call Handling Standards (ACPO, 2005). The key performance indicator for *Call Handling* is 'call answering time'. This is the amount of time between the call entering into the *Call Handling system* and the call being answered by a member of staff. The national targets are based upon the percentage of emergency calls answered within 10 seconds and percentage of non-emergency calls answered within 30 seconds; a force should be answering 90% of all calls within these time frames. Therefore, attempting to reduce the time that is perceived to be wasted will benefit *Call Handling* performance and, therefore, callers. This reframed how the researcher thought about WASAN and how it could be made clearer to participants. Thus, the waste to be analysed changed from being tangible to something that was intangible—time.

PQ3 asks what are the important elements required in a systems definition? The elements included in the system definition in nuclear are not present in *Call Handling*; therefore, the aim of the pilot was to understand which elements should be included in the definition during Stage A. In the pilot, each participant was responsible for defining all the Inputs, Outputs, Channels In, and Channels Out considered in the model along with the system purpose. This process was time–consuming, thereby increasing the overall interview length. The differences between definitions led to the participants developing slightly different views of the system. As with the waste, the validity of combining models that viewed a system differently into a single composite model was questioned. If systems were defined differently with different channels and a different purpose, then they will be analysed in a different manner. The inconsistencies in the system definition would make individual models in the developed Stage B incommensurate with each other, thereby leading to conflicts when they were aggregated. To eliminate the inconsistencies that could arise from divergent system definitions, Stage A was modified after the pilot. In the new format, only one Stage A interview would take place. A single boundary would be agreed in Stage A, which would be presented to participants at the beginning of Stage B. The boundary would include the system purpose, waste to be reduced, and channels to be considered. Participants in Stage B should agree with (or at least accept) the system definition from Stage A for the Stage B interview to take place. For the output from Stage A to be acceptable to the Stage B participants, the definition would either have to be agreed by a single powerful participant who had the authority and respect of the participants and knowledge of the system, or defined by a group that, as a whole, possessed these attributes. In *Call Handling*, for pragmatic reasons a single participant was interviewed to define the boundary of the system in Stage A. The system owner for *Call Handling* was selected to participate in Stage A for the *Call Handling Study*. They were responsible for defining the waste, the system boundary, and system purpose. These three elements were validated by others with knowledge and experience of *Call Handling*. The Stage A output was then used to structure and inform each interviewee of the parameters of the system in Stage B before the interviewees provided insight to identify and resolve system weaknesses.

PQ4 considered what keywords were best to ensure that participants are able to generate sensible actions. In nuclear, the keywords were taken from the WMH. The WMH was a tool known to participants within nuclear and was proven within this context to be useful in reducing wastes within that environment and, thus, had legitimacy. This was not the case for *Call Handling*; WMH did not have any history of use within the Police Force and was not known to the potential participants. The researcher was concerned that conceptually the keywords from WMH would not translate across to the *Call Handling* context; they may cause confusion among participants as they seemed abstract in a non-production context. They also lacked the legitimacy in a Police context, as the WMH was not well known or used in Police research. In the pilot, the first three participants generated their own keywords to test on their wastes. The final three used the WMH as keywords in lieu of generating their own. The group of participants generating their own keywords seemed to struggle to identify appropriate keywords that worked in the context, thereby leading to significant prompting from the facilitator. For the second group (those using the WMH), only 'Avoid' and 'Minimise' were found to be useful for participants; the other keywords did not generate sensible actions relating to waste avoidance. Comparing the self-generated keywords with the WMH identified that the self-generated keywords were ways in which to achieve the two keywords 'Avoid' and 'Minimise'. Table 8 details all the self-generated keywords and groups them into either 'Avoid' (Column 1) or 'Minimise' (Column 2). Therefore, the analysis of external wastes was modified to only use the two keywords 'Avoid' and 'Minimise' from the WMH.

Avoid	*Minimise*
Better filtering of calls	Getting all useful information from the job
Wrong calls	Quicker management of calls
Avoid calls	Reduce the length of calls
Reduce the number of unnecessary call backs	Efficiency through knowledge
New channels	

Table 8 Participant generated wastes categorised into 'Avoid' and 'Minimise'

The final step of the pilot study was to test the updated version of WASAN before it was deployed in *Call Handling* at the UK Police Force. The new system definition, waste, and keywords were used in a test run to develop a model and operationally ensure that the modifications to WASAN would work in *Call Handling*. The test was conducted by the researcher and an experienced facilitator. The researcher acted as a participant, with the facilitator taking the researcher through Stages A and B of WASAN. The researcher was able to use the knowledge collected from the set of 6 interviews and their own experience working with Call Handlers for two years to build a test model. The test was successful with the new system definition, waste, and keywords working together to build a model which could have been analysed by the researcher.

4.2.4 Conclusions from the Call Handling Pilot Study

Before this research project, WASAN had only been designed for use within a nuclear context and not beyond; the only proven uses of WASAN before this study were within nuclear processing facilities. As the development process for original WASAN was not concerned with generic applicability, there was concern of the transferability of WASAN to a new context. Therefore, before rolling out the full scale Call Handling Study, there was a small-scale Call Handling Pilot. The pilot was needed to trial Stages A and B, because the mode by which they were operationalised had changed. In the original WASAN, all participants were included in a focus group for Stages A and B; however, for pragmatic reasons, this was not possible in the Police. The Pilot Study found three shortcomings that hindered transferability of WASAN. These were the definition and identification of waste, the definition of the system boundary, and the keywords used in the keyword analysis in Stages B1 and B2. These three elements were redesigned to ensure applicability and transferability in the police. Once redesigned, the new WASAN was trialled again with the researcher acting as participant, while an experienced facilitator took the researcher through the WASAN process. The newly redesigned WASAN successfully built a model that could be taken into the latter stages of analysis. Therefore, WASAN was ready to be deployed more widely within *Call Handling*. Next, the chapter reports the Call Handling Study where this revised WASAN methodology was implemented.

4.3 Call Handling Study

The key questions regarding how WASAN could be deployed in *Call Handling* were answered during the Call Handling Pilot. Therefore, WASAN could be deployed more broadly within *Call Handling*. This section describes the Call Handling Study. The data collected in the full Call Handling study was kept separate from the Call Handling Pilot; none of the data from the pilot study was included in the analysis of the Call Handling Study. The changes to the methodology implied that the models and data collected during the pilot were not commensurate with the models and data collected during the Call Handling Study. Where possible, staff were not included in both studies; however, certain roles which offered a unique perspective needed to be included in both, such as the Customer Contact Manager. As this position was critical in understanding *Call Handling* and was only performed by one person in the force, these roles had to be included in both studies. The same is true for the Quality Assurance Officer, who was included in both studies; however, no other staff was included in both the Pilot Study and the main Call Handling Study.

4.3.1 Stage A

WASAN, as described below, is the same approach that was used in Switchboard*, Crime Desk, and Crime Admin*. Stage A required a global definition of *Call Handling* that could be accepted by Stage B participants at the beginning of their interview. To maximise legitimacy of the definitions from Stage A, the Customer Contact Manager was interviewed in Stage A. The Customer Contact Manager was able to provide a comprehensive description of *Call Handling* using a combination of their knowledge and existing documentation, such as role profiles and system targets. Through facilitation, these descriptions were modelled into a single written definition of the system properties. The output from the Stage A interview with the Customer Contact Manager was an agreed system boundary which would be used to focus participants' thoughts in Stage B. The first task in Stage A was to agree the waste to be examined; as found in the *Call Handing* Pilot, the waste to be reduced was time. That is not to say that any time spent by a Call Handler with a customer is wasted; however, occasionally a Call Handler is on the phone with a customer unnecessarily and this may not be useful and therefore should be reduced. For example, if a Call Handler spends 10 minutes processing a phone call from the public, these 10 minutes can never be reused or recovered. If only 4 of the 10 minutes were actually needed to receive the necessary information then the additional 6 minutes spent on the task were spent on irrelevant activities that had no benefit to the caller or the organisation. Therefore, we can split time spent on this task into two categories, useful time and wasted time. In some instances, none of the time spent on a call is useful; for example, if a caller was passed to *Call Handling* with a query that cannot be processed by *Call Handling* then the entire time spent with the caller is wasted time. Eliminating wasted time would make the process more efficient without reducing service delivery. To understand what time is waste and what time is useful, we need to understand the purpose of *Call Handling*. The time spent on activities that contributes to the system purpose is considered useful time; time spent on activities that do not contribute to the system purpose is not considered useful and therefore considered wasted time. With a clear system purpose, the analysis can focus on reducing time spent on activities which do not contribute to the system purpose and are considered wasteful. The following was the agreed system definition of Call Handler from Stage A:

"The call handlers answers calls as quickly as possible; once answered they identify quickly and accurately what and where the incident is; then use risk matrix to understand risks to individuals, groups/town and officers who may attend using information from intelligence systems; identify an appropriate response; recording information accurately on the correct IT system; give the correct information back to the caller. They may also need to liaise with other areas of the force (crime desk) and/or other forces/emergency services, and companies/partnerships and transfer calls to other departments."

The final element of the definition outlined the targets for Call Handlers; these were taken from the National Call Handling Standards which state that "90% of all external emergency calls to be answered within 10 seconds" and "90% of all external non-emergency call to be answered within 30 seconds" (ACPO, 2005 p.72). Including the targets in the definition was believed to ground participants' thoughts on why wasted time should be eliminated as it directly impacts their ability to meet these targets.

4.3.2 Stage B

Stage B is the idea-generation phase of WASAN; participants' thoughts are structured through facilitation to identify recommendations that could reduce the impact of waste on the *Call Handling system*. A total of 11 participants were interviewed, and they were selected to ensure a wide range of experiences and knowledge of *Call Handling;* between them they offered a range of perspectives on how waste could be reduced. At the beginning of the interview, the purpose of the study and the interview was explained. In addition to this all issues regarding data protection, the participant's right to anonymity and right to withdraw were explained, and any questions from the participant pertaining to these issues were answered. Finally, a request was made to voice-record the interview. When the interviewee had consented to participation, the formal interview commenced and if agreed the voice recorder began recording. At the beginning of the formal interview, participants were shown the definition of *Call Handling* from Stage A to check their own view of *Call Handling* aligned with the perspective taken by the project, as derived from the Customer Contact Manager during the Stage A interview. All 11 Stage B participants agreed with the definition, thereby adding validity to the original definition. Participants were asked to identify what activities or instances they have seen or experienced where they believed time was being wasted. As a point of clarification, it was explained to participants that wasted time was doing tasks that did not contribute to the goals of *Call Handling* as per the Stage A definition. If further explanation was needed, the generic examples relating to wasted time given at the beginning of this section were provided. Most wastes identified by participants were self-explanatory, both in terms of what they were and how they would lead to wasted time. These included wastes such as *Calls not for police service, misrouted calls, and multiple reporting of incidents.* In some cases, the waste was more ambiguous—for example, *organisational risk aversion*; in these cases, participants identified the reasons why the waste is generated and described how the potential waste can affect the *Call Handling system* [Figure 21].

Using the potential major wastes from the source-matter ...	Identify the reasons why the waste is generated	Describe issues of how the potential waste affects the system
Organisational Risk Aversion	Influences people behaviour in the control room ;;; People are anxious and nervous that they could be liable for making wrong decisions ;;; Can act as a barrier to managing calls ;;; Call handlers want to avoid the possibility of making the wrong decision to the stress of investigation or	Calls take longer as they are putting more information on the call ;;; Call handlers use wrap up time to ensure all information is recorded ;;; An officer is not dispatched usually until the call is sent by call handler, these things will reduce response time to the public ;;;

Figure 21 Defining avoidable wastes

Once the participant felt that they had identified and adequately defined all the wastes, the interview progressed to keyword analysis. For this stage of the analysis, wastes were divided into internal wastes and external wastes as different keywords were applicable to each category of waste. External wastes are those which enter the system from an upstream system, for example, *Calls not for police service*. Internal wastes were those generated as a result of aspects internal to *Call Handling*, for example, *Too many Call Handlers on duty*. For external wastes, the keywords used were 'avoid' and 'minimise' from the WMH. Avoiding a waste would require taking action that prevents the call entering *Call Handling* in the first place. For avoidable wastes, this is the most desirable option as it saves the most time. Minimising a waste identifies actions that reduce the length of time taken to deal with that call, given that it has already entered the system. This recognises that not all wastes can be avoided, but some action can still be taken against wastes that cannot be avoided once they have already entered the *Call Handling* system. Avoiding wastes is more desirable than minimising them; this is drawn from the principle of ALARP and is explicit in the WMH. As with the Call Handling Pilot participants, responses were recorded in a tabular format. Figure 22 depicts an extract from the external keyword analysis from one of the interviews. In this interview, three wastes are considered; these are listed in the first column of Figure 22, that is, *'Call Handlers not taking control of the call', 'Call routed from Switchboard which are not for the Control Room'* and *'Members of the public call the Police for non-Police matters'*. The wastes are listed in [the grey] column one and the keywords listed across the top in [the grey] row one. The interviewees began by choosing the waste that they felt was most important to be analysed (this was so if they were called back into the control room; the most important wastes were more likely to have been considered); then the facilitator used the keywords to structure the analysis of the chosen waste. For example, "*Using the waste (Call Handlers not taking control of the call)—what are the issues around avoiding the generation of* *this waste"*. Identifying the issues surrounding waste avoidance recognises that implementing actions that avoid a waste may introduce unintended consequences into the system; the potential for these consequences should be considered by the participant before they identify actions. Next, actions surrounding avoiding the waste are considered using the same keyword prompts: "*Using the waste (Call Handlers not taking control of the call)—what are the actions around avoiding the generation of this waste"*. Responses to each prompt were recorded in the corresponding box in the figure. This process was repeated for '*minimise*' and then repeated for 'avoid' and 'minimise' for each waste.

	What are the ISSUES around **AVOIDING** the generation of this waste	What are the ACTIONS around **AVOIDING** the generation of this waste	What are the ISSUES around **MINIMISING** the generation of this waste	What are the ACTIONS around **MINIMISING** the generation of this waste
Call handlers not taking control of the call		Identify call handlers that may need more training on taking control of the call then supply on-going training ;;		Could pass these callers to management if the call handler cannot manage the caller ;;;
Calls routed from switchboard which are not for Control Room	High turnover of staff in Switchboard means less experience in managing calls ;;; If switchboard spend longer on calls they may begin to miss their targets ;;;	More training in what can be routed through ;;; spend time sat with call handlers to gain better awareness of the role ;; Need to keep switchboard up to date with policy changes ;;; encourage switchboard to spend a little longer with callers ;;;		
Members of the public call police for non police matters	Don't want to put off people calling when it is a police matter ;;;	Education to the public around what police deal with ;;; design and promote numeric to advertise what is police matter;;; publicise how much time wastes with non police matters ;;;Better promotion of 101 number to stop non-emergency calls on 999 ;;;		Call handlers need to take control of the call ;;; More training assertiveness with difficult callers ;;;

Figure 22 External waste keywords analysis in Call Handling

The keyword analysis for internal wastes was akin to a qualitative sensitivity analysis. In quantitative OR, a sensitivity analysis measures how a solution changes as various inputs change (Albright & Winston, 2007). The sensitively analysis sought to understand the behaviour of each internal waste by considering how the *Call Handling system* would react if different levels of the waste were present within the system. Understanding these behaviours of waste in the system can lead the participant to learn how to mitigate against potential adverse effects on the system from the waste. The sensitivity analysis was performed by considering the waste in two opposing states within the system: too much and not enough. This is shown in Figure 23 where the waste "*Wrong number of Call Handlers"* is analysed. The two opposing states of the waste are shown in the [grey] first column. In the [grey] top row, the two prompts to understand how the opposing states affect the system are listed. To conduct the analysis, the interviewee selects one of the states of the system to examine. The facilitator then uses the prompts to examine how the system is affected when the waste is in the given state. For example, "*What are the concerning issues of the state of the waste (Too many Call Handlers) on the management of Call Handling"*. The issues are recorded in the table before the participant is asked *"What are the potential actions to mitigate against these concerning effects".* This process is repeated for all wastes in each opposing state.

	What are the concerning issues of ... on the management of [redacted]	Potential actions to mitigate against these concerning effects
Too many call handlers	Having too many call handlers at one time means there are not enough at other times during the week ;;; Sometimes too many staff for capacity ;;; Too many staff in the control room may cause the system to slow down ;;;	More evenly balanced staffing across the 24h period ;;; Move some staff from lates back to earlies ;;; move more staff off lates to an earlier shift ;;;
Not enough call handlers	Will not get calls answered within time which creates risk ;;; Will cause stress across the staff as they are working harder ;;; calls not dealt with properly as they may be rushing to answer the next call ;;;	Could move some to the lates shift back to an early shift ;;; Look at calls per person per hour to see if staff levels is balanced with calls ;;;

Figure 23 Internal waste keyword analysis of Call Handling

After each interview, the data recorded in a tabular format model was transposed to a list of identified wastes and action. This was cross-referenced with the recording to ensure that no data was omitted. This document was sent to the participant to check and validate; this gave the participant an opportunity to raise any additional wastes or actions which they had thought of subsequently and provided an additional chance for participants to withdraw from the study. Once validated by the participant, the data was taken forward to subsequent stages of analysis. Interviewees from the 11 Stage B interviews for *Call Handling* individually identified 44 sources of waste and 157 actions aimed at reducing the impact of the wastes on the *Call Handling system*. There was considerable overlap from the responses in the 11 interviews so the wastes and actions were aggregated to form a composite model where the responses were themed. Figure 24 shows how 7 similar wastes were themed into the waste *Non-Police calls*. The concepts around the outside are wastes taken from individual Stage B interviews. In the centre of the model is the themed waste identified by the researcher (RN is an individual respondent number; the number at the beginning of each concept is a unique ID number). The theming process reduced the number of wastes from 44 to 17 and the number of candidate actions from 157 to 76. Each map was shown to a Control Room Supervisor who validated that the responses had been sensibly themed. The themed responses were carried forward to Stage C.

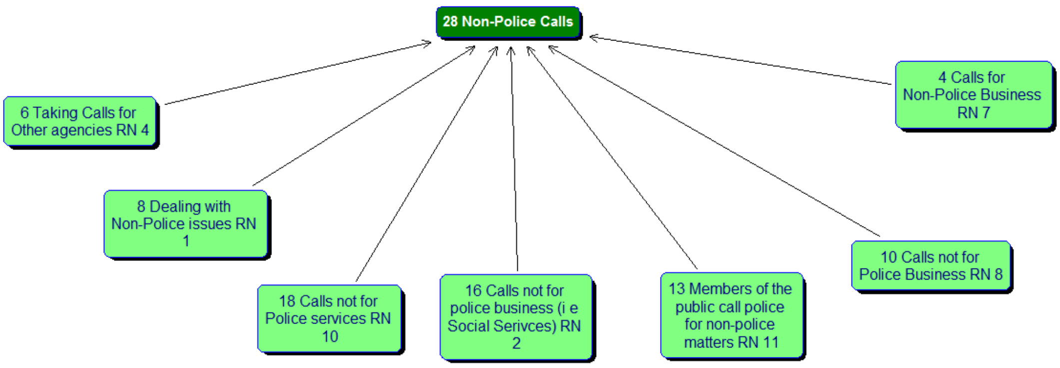

Figure 24 Theming the sources of waste

4.3.3 Stage C

Stage C qualitatively evaluated and prioritised the candidates' actions using an action evaluation grid (AEG). The first step was to interview the Customer Contact Manager to identify three qualitative criteria which candidate actions could be evaluated against. The Customer Contact Manager discussed the types of criteria that would be most appropriate to successfully delineate the strong actions from the weak actions. From here, a list of potential criteria was developed which were narrowed down to the three most appropriate criteria by the Customer Contact Manager. As a final check, the five criteria suggested by Keeney & Raiffa (1993) which can be used to judge the AEG evaluation criteria were applied to the proposed evaluation criteria. These are completeness, operationality, decomposability, absence of redundancy, and minimum size. Completeness requires that all attributes which are of concern to the decision maker are included.

Operationality requires that the criteria, and categories within them, are specific enough for a decision maker to compare and evaluate the different actions against each criterion effectively. That is, each action can be put into one and only one category for each criterion. Decomposability implies that the performance of an action in one criterion can be judged independently of its performance in the other criteria. Absence of redundancy requires that two or more criteria do not represent the same thing. If they do then one of the criteria could be redundant and should be removed. Minimum size requires that there are not too many criteria, as this would make the AEG too large and impractical to use (Goodwin & Wright, 2004). After checking against these five points, the three criteria chosen were 'Alignment with the long-term vision', 'Savings to investment ratio', 'Risk to the public, staff and officers'. Each criterion was divided into three or four categories which an action could be judged to be in. The categories were chosen to delineate the candidate actions into categories representing good, fair, and poor performance with respect to each criterion. The three criteria were then used to build the structure of the AEG [Figure 25]. In the AEG, each criterion is aligned to one of the first three columns with the rows dividing each column into the good, fair, and poor categories. Each row represents a unique combination of categories across the three criteria. The fourth column is a space to list the themed actions which fit into the three categories represented by that row. In Figure 25, the real rankings have been omitted for confidentiality; however, 10 example actions have been included. The AEG was completed during a focus group of key stakeholders including both decision makers (to increase political feasibility) and technical specialists (to increase substantive rationality) (Eden, 1992). The participants were the Superintendent for Customer Contact, Customer Contact Manager, a Control Room Supervisor, two Systems Administrators and the Quality Assurance Officer. The majority of these participants worked on less operational duties and also tended to work normal business hours. Therefore, it was possible to find a time when the requisite number and composition of staff could make a single focus group. It also would have been impractical to hold individual Stage C interviews and aggregate the results. The participants in the focus group worked systematically through the themed actions, rating them by each of the three criteria and then marking the agreed choice by writing the action number in the fourth column of the corresponding row in the AEG. All participants openly discussed each action in relation to each criterion; however, the final decision was made by the Superintendent, as the most senior participant, who physically recorded the group's decisions into the AEG. It was important to ensure the participation and buy in (Eden, 1989) from the most senior decision maker. The structure and rank system within the Police encourages an authoritarian approach to leadership and decision making (Bruns & Shurman, 1988); thus, the full participation of a senior officer showed leadership in the decision making process. It also should help with implementation of the proposed actions. During the focus group, there were no cases where after discussion participants strongly disagreed with each other over the final ranking, thereby making the process broadly unproblematic. However, there was initial disagreement regarding the ranking of many of the actions. In these situations, either the facilitator or superintendent probed the divergent views as participants came to agreement. The final step of Stage C was to identify priority levels for each action based on how it had been categorised in the AEG. These priorities influenced if an action was likely to be taken forward to Stage D or not. To avoid ratings in Stage C being influenced by these priority levels, two weeks after the main focus group, a one-on-one meeting was held with the Customer Contact Manager to agree on which rows on the grid would attract which priority levels. These are shown in the right-hand column of Figure 25 (high [white cells], medium [light grey cell], and low [dark grey cells]). In the example, actions 2, 5, 8, and 10 would be considered high priority, actions 1 and 9 medium priority, and actions 3, 4, 6, and 7 low priority. Each action and the corresponding action was taken forward to be considered in Stage D.

Alignment with alliance blueprint	Savings to investment ratio	Risk to the public, staff and officers	Evaluated actions against criteria
High correlation with the blueprint – timeframe and ethos	High savings compared to investment	Decreased overall risk	**Action 5**
		Neutral overall risk	**Action 2**
		Minor increased overall risk	
		Major increased overall risk	
	Medium savings compared to investment	Decreased overall risk	
		Neutral overall risk	**Action 10**
		Minor increased overall risk	
		Major increased overall risk	
	Low savings compared to investment	Decreased overall risk	
		Neutral overall risk	**Action 1**
		Minor increased overall risk	
		Major increased overall risk	
Medium correlation with the blueprint – timeframe and ethos	High savings compared to investment	Decreased overall risk	
		Neutral overall risk	**Action 8**
		Minor increased overall risk	
		Major increased overall risk	
	Medium savings compared to investment	Decreased overall risk	
		Neutral overall risk	
		Minor increased overall risk	
		Major increased overall risk	**Action 3**
	Low savings compared to investment	Decreased overall risk	**Action 9**
		Neutral overall risk	
		Minor increased overall risk	
		Major increased overall risk	
Low correlation with the blueprint – timeframe and ethos	High savings compared to investment	Decreased overall risk	
		Neutral overall risk	
		Minor increased overall risk	
		Major increased overall risk	
	Medium savings compared to investment	Decreased overall risk	
		Neutral overall risk	
		Minor increased overall risk	**Action 6**
		Major increased overall risk	
	Low savings compared to investment	Decreased overall risk	
		Neutral overall risk	
		Minor increased overall risk	
		Major increased overall risk	**Action 4, Action 7**

Figure 25 Action evaluation grid

4.3.4 Stage D

Stage D is the final stage of WASAN and aims to agree to a set of program deliverables for the project based upon the actions categorised as high priority in the AEG from Stage C. The deliverables should improve the system while also being commensurate with the goals of wider systems. *Call Handling* is part of a wider department—*Customer Contact*, which sits within *Incident Resolution*; actions which benefit *Call Handling* do not necessarily benefit wider systems. For example, an action which reduces the length of time callers are on the phone but unnecessarily increases percentage of calls where a Police Officer is deployed is not aligned with the organisation's wider goals. The action may reduce the time of the call but would place huge demands on the Police Officers in Incident Resolution who have to attend the additional calls for service as a result of implementing the action. Stage D sets the program deliverables within this wider context. The Customer Contact Manager and a Control Room Supervisor participated in a focus group to decide a work programme to implement. All low priority actions were discarded to focus the actions rated high and medium priority in Stage C. Of the remaining actions, some were initially discarded as they overlapped with existing work streams, were misaligned with wider organisational goals, or not currently considered a priority for Call Handing. The final list of actions was agreed upon and then an order of precedence was considered for actions—recognising that some actions needed to be completed before others could commence. Key individuals within *Customer Contact* were identified to take ownership of specific actions to increase accountability in the process.

4.3.5 Feedback of results

Finally, the results of the study were communicated to the Control Room Supervisors at their bi-weekly management meeting. The recommendations and methodology was reported at the meeting along with delivering the final written report. In this meeting, 4 of the 5 Control Room Supervisors, the Chief Inspector for Customer Contact, and the Quality Assurance Officer were present. Feedback for the presentation was sought from the attendees, all of whom had been involved in at least Stage B or Stage C; since the Customer Contact Manager was not present, a separate meeting was held with them.

Overall, the feedback was positive; when asked about the feasibility of the recommendations, the Chief Inspector remarked, "*straight away the training actions to me there all do-able*". When asked about WASAN as a process, the Chief

Inspector said, *"So just to ask us the question, even probably never ask ourselves that question have we about well. What do we think is waste and what affects the performance. So I think that is useful looking at the front end, you know there is stuff we perhaps don't have control of but can we have an impact on it"*. With one of the Control Room Supervisors adding "*It's quite good someone comes in and brought it all together if you like cos I think we all do it without knowing it discussing individual things on different shifts but it's never brought together and presented in a way forward if you like so that was good"*. This feedback shows that WASAN was able to produce politically feasible actions. The process prompted the staff to think in a new way about how they manage *Call Handling* and what affect they can have on the generation of waste if they are proactive. Staff was also pleased with how the process was packaged, drawing thoughts together from across a range of staff and presenting a coherent final set of recommendations.

4.4 Generic Development of WASAN

This section explores the development of WASAN from a specific approach to show how it is generic enough to be applied in multiple contexts. Understanding how to develop generic properties in an approach is a key element to increasing our understanding of the pluralism of PSMs. This is shown in question 10 of the four-pillar framework, which identifies how PSM have generic applicability ("*Is the model building process suitably generic so it can be transferred to multiple problem contexts?*"). Therefore, a valuable contribution to knowledge can be made by understanding the principles to take an approach from bespoke to generic. This section responds to this need by answering RQ2: "*How can PSMs be developed into suitable generic approaches applicable in multiple problem contexts?"*. To answer this research question, this section draws from the *Call Handling* Study from Section 4.3 to understand how the philosophy and methodology of WASAN was developed from a bespoke approach used in the nuclear industry to a generic approach that could be applied in multiple contexts.

The original WASAN approach was developed for use in a nuclear context and, as such, at a descriptive level there was no distinction between the factors which were to be applied rigidly in the same manner regardless of context and those which should be adapted depending on context. For example, in the original methodology, the system definitions in Stage A identified elements that are specific to a nuclear processing facility and used terminology specific to the nuclear industry. This exact pro-forma would not be sufficient to define the boundary of a system in a different context; therefore, WASAN in the form identified in nuclear is not generic. However, eliminating the requirement of a system definition from WASAN would change the approach beyond its original purpose and philosophy. Therefore, a balance must be struck where some elements should be changed and others must remain.

This section divides WASAN into those elements which are contextual and should be adapted to the local context and those elements which are part of the WASAN philosophy and should remain fixed in all WASAN applications. To identify these two classes of elements within WASAN, we must reduce WASAN into a set of constituent parts which can be analysed and (where needed) developed separately. Considering the elements in isolation implies the development of one element should not compromise the integrity of other elements. To reduce WASAN into a set of individual elements, the project draws on the notion of smart bits introduced in 2.6.1.

Reducing WASAN into a set of smart bits which can be developed independently creates a problem. Developing the individual smart bits of WASAN in isolation may affect the ability of WASAN to perform its central aims. That is, the emergent properties of WASAN may have been affected by developing smart bits. Therefore, the project must put in place adequate checks and balances to show that the aims and method of WASAN have not been compromised or altered beyond their original intention. These original aims and methods that define WASAN are all contained within the WASAN philosophy outlined in Section 2.6.2. To show that new developments to the approach have not changed WASAN beyond this scope, the project will compare the developed methodology to this original philosophy. This will check if the approach still achieves the ontological, epistemological, and axiological aims of WASAN. The philosophy of WASAN acts as a check and balance that developing some of the smart bits has not altered the approach's philosophy, that is, the new approach is still WASAN.

4.4.1 Analysis of smart bits to identify generic development of WASAN

This section analyses seven smart bits of WASAN to identify the elements which are context-specific and those which should be replicated rigidly across all interventions. Any elements identified as context specific must be able to adapt to the context in which they are applied and so need to be developed to be flexible enough to work within multiple contexts. The elements which must be replicated regardless of context (called methodological elements) need to be preserved, as these are the elements which translate the WASAN philosophy into practice. The seven smart bits considered are mentioned below:

- Group vs. individual model building
- System boundary definition
- Keyword analysis
- Waste management hierarchy
- Sensitivity analysis
- Action evaluation grid
- Higher authority signoff

To distinguish between WASAN as applied in the original nuclear context and WASAN as applied in the UK Police Force, the term 'original' (such as 'original WASAN' or 'original approach') will refer to WASAN in nuclear and 'WASAN' will refer to WASAN as developed in *Call Handling*, unless explicitly stated otherwise.

Group vs. individual model building

The first smart bit considered is how WASAN can be operationalised. For the purposes of this project, operationalised refers to the manner in which an approach is deployed and how data is collected. In the original approach, WASAN was deployed in focus groups for Stages A–C. Due to constraints already identified, it was not possible to abstract all relevant participants from their regular duties to participate in a single focus group. Therefore, how WASAN was operationalised was adapted so interviews could be conducted one-on-one in Stages A and B. This created a problem which was identified in the Pilot Study; if individual participants defined their own boundaries during Stage A, there was a chance that the model they built would have a slightly different conception of the *Call Handling* system than the other participants. Therefore, models may not be commensurate and so could not be aggregated into a composite model for analysis. To redress this, WASAN relied on the hierarchy of systems to pass the responsibility of specifying the system definition to a participant with more authority than an individual Call Handler.

Vertical recursion states how systems in an organisation are arranged in a hierarchy with lower order systems nested within higher order systems. Every system contains and is contained within another system (Beer, 1979). Tejeida-padilla & Badillo-pin (2010) compare this to Russian dolls, where each doll is nested within a larger doll and contains a smaller doll. To distinguish between systems at different recursive hierarchal levels, Jackson (2003) suggests the following naming convention. The Level 1 System is the system-in-focus, which is called *Call Handling* in the study. Level 2 is the system contained within Level 1, which is the individual Call Handlers in the Police, as the individual Call Handlers comprise the *Call Handling* System. System 0 is the system which contains Level 1; in the Police, this is *Customer Contact; Call Handling* is one function within *Customer Contact.* This hierarchy, along with Level -1, is illustrated in Figure 26.

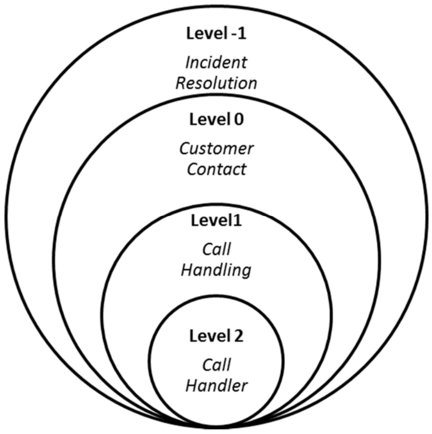

Figure 26 Hierarchy of vertically recursive systems in the UK Police Force

To maximise the legitimacy of the system definition, the single participant interviewed in Stage A who was responsible for defining the *Call Handling system* was the Customer Contact Manager. The Customer Contact Manager was the *Call Handling system* owner and was from the Level 0 system. With their authority over the *Call Handling system*, the Customer Contact Manager was able to provide a definition of *Call Handling* that the Call Handlers should accept. The Stage B interviews were with individuals from *Call Handling* or with knowledge of *Call Handling*. Thus, as they were interviewed as individuals, they represented the Level 2 system. Aggregating the models from all Stage B interviews created a composite model which was representative of *Call Handling* as the Level 1 system. Participants in the Stage C focus group were representatives from the Level 1, Level 0, and Level -1 systems, thereby providing a wider knowledge base to evaluate the themed actions and increasing political feasibility through participation and negotiation. Finally, Stage D considered the actions for *Call Handling* in terms of the goals and aims of Level 0 and Level -1 systems.

Operationalising WASAN in individual interviews led to developing the explicit use of different hierarchical systems within the intervention. As the original approach was operationalised within a focus group that included all participants in Stages A–C, there was no need to go to Level 0 for the system definition in Stage A. The only hierarchy considered in the original WASAN is in Stage D, where actions were considered in relation to System 0's aims.

This new way of operationlising WASAN can be used in two modes. The first mode is with all participants included in focus groups, which is as per the original approach. The second mode is with individual interviews in Stages A and B, which is as per WASAN in *Call Handling*. Having two modes to operationalise an approach in is not unique to WASAN; both SSM and SODA can be used in two modes. Mode 1 in SSM operationalised the approach in the traditional manner as a formal group level application; Mode 2 SSM is applied by an individual to structure their own internal thinking (Checkland & Scholes, 1999). For SODA, the two modes are more similar to WASAN; the first mode is operationalised through individual participant interviews with the data from each interview building an individual cognitive map of the situation according to the participant's own personal definitions. These individual Level 2 models are then combined to form a composite map of the situation, thereby creating a Level 1 model. The second mode is commonly referred to as Journey Making where cognitive maps are built during a focus group with participants jointly contributing to the definition of the issue under consideration.

System boundary definition

The second smart bit to be considered is the system boundary definition from Stage A. As identified in the Call Handling study, the way the system boundary was defined in the original approach during Stage A was not appropriate for the *Call Handling* context. The system defined in the original approach was a technical waste producing system, managing tangible physical waste under tight regulatory controls. The following elements of the system were included within the original definition:

- The source-matter (SM) that causes waste.
- The (A)im in processing the source-matter.
- Engineering, physical, managerial (S)afeguards: to identify activities that prevent avoidable waste so actions may strengthen (avoid compromising) these.
- The avoidable (W)astes which the source-matter creates.

Definitions for each waste identified the following aspects:

- The avoidable (W)aste: to identify the material being defined.
- The (R)easons the waste is generated.
- The physical (F)orm of the waste.
- Optimal (C)onditions for managing the waste.
- (B)ehaviour of the waste.
- Additional (A)ssumptions about waste minimisation.

(Shaw & Blundell, 2010)

Many of these elements simply do not exist in *Call Handling;* for example, source-matter refers to materials contaminated by nuclear waste which smear nuclear contaminant onto other materials when they come into contact with them. Smearing is largely unique to certain types of waste and not applicable to intangible wastes like those in *Call Handling*. Therefore, the type of system definition from the original methodology does not translate to the *Call Handling* context. The elements in the original approach are context-dependant and so cannot be used as part of a generic methodology. However, the system definition is still a core methodological element to the WASAN methodology and so more generic requirements for systems definition is needed for the final methodology.

In a generic WASAN, the first thing that needs to be identified is the system which is to be the focus of the intervention. Second, is the waste to be reduced. Originally, WASAN defined waste rather narrowly as "materials that have no value or have been contaminated" (Shaw & Blundell, 2010 p.350) such as contaminated pond containers, sludge, insoluble/soluble waste. To develop WASAN we need a more generic definition to reflect a wider set of operations and wastes. Pongrácz & Pohjola (2004 p.151) propose that "a thing is waste because it has no purpose – either because it has never been assigned one, or because it has not been assigned a new one after the first was fulfilled". Therefore, waste is a by-product of operations which have no useful purpose and has a detrimental effect on performance. From *Call Handling*, it is evident that waste can also be intangible, such as lost time. Combining these elements, we create a more generic definition of waste. For WASAN, waste can be defined as: *Something tangible or intangible that arises in a process and unnecessarily compromises system performance. Thus, it is worth monitoring and managing waste because it is either valuable in its original form or costly when it compromises performance.* The new definition of waste shows how an approach must be flexible so contextual factors can be considered, thereby ensuring fit between area of application and methodology. Next, the definition must identify the aim and purpose of the facility in focus. This helps to understand which wastes are avoidable as opposed to unavoidable wastes. For example, in the Call Handling Study, the waste being reduced was Call Handler's time. Not all of the time spent with callers could be reduced as it was contributing to the system purpose, but there were instances where unnecessary time was spent with a caller. This unnecessary time is avoidable and so could be reduced without compromising the ability of the system to achieve its purpose. Only by comparing the system purpose with how the system actually runs can participants identify the elements which are wasteful and can be eliminated without compromising the system's ability to achieve its purpose.

The final element included within the Stage A system definition is the Channels In and Channels Out of the system which the waste enters. One of the defining features of WASAN is how it considered the channels entering the system from upstream systems in the analysis. In *Call Handling*, the 'Channels In' were the incoming phone calls, as this was where most of the wasted time was generated. We could have expanded the analysis to include other Channels In, such as email or letters, but these were not considered major potential sources of waste and so were excluded from the analysis. These channels are identified to narrow the focus of the intervention in Stage B. Thus, the following elements are required in a generic WASAN Stage A system definition:

- The system in focus—identifying the system which WASAN will be applied to.
- The waste to be reduced—this waste could be tangible or intangible that arises during the production process and is worth preserving.
- The aims and purpose of the system in focus—this will help participants in Stage B to identify the activities that are wasteful as they do not contribute to the aims and purposes of the system.
- The channels into the system—this narrows the focus of analysis in Stage B.

Keyword analysis

The third smart bit to be considered is the keyword analysis; this is the mode of analysis used to structure Stage B data collection from the original approach. The actual process of the keyword analysis translated across to *Call Handling*. Taking a set of keywords and using them to structure the manner in which participants thought about waste was context-free, drawing purely on methodological factors. Therefore, the process of the keyword analysis did not require any further development as it was already suitably generic.

While the process of the keyword analysis did not need to change based on the context, the actual keywords used did not fit with the *Call Handling* context. These keywords are considered a separate smart bit from the process of the keyword analysis and are considered separately below.

Waste management hierarchy

The fourth smart bit to be considered is the use of the WMH as the keywords during the Stage B1 (analyse external operations) keyword analysis. The Call Handling Pilot and Study clearly showed that the selection of keywords is a key component to the success or failure of the intervention in Stage B. Using all the WMH keywords was confusing for participants as 'Recycle', 'Reuse', and 'Dispose' were not contextually relevant to an intangible waste. However, 'Avoid' and 'Minimise' were found to be useful to interviewees when thinking about actions to reduce external wastes from upstream systems entering the system in focus. For example, after being prompted with the keywords, one participant said, *"the wastage isn't with us … you need to take it further back down the pipe and say are the people that need to be dealing with these people dealing with it in a positive way … at the source".* The two keywords used in *Call Handling* was applicable in both *Call Handling* and the original nuclear context, but this does not mean that they be considered context free and therefore generic. It is likely that both 'Avoid' and 'Minimise' are applicable to both tangible and intangible wastes with the remaining keywords from the WMH only shown to be applicable to production systems. Therefore, instead of a rigid set of keywords that must always be used during a keyword analysis, the project advocates adopting an approach similar to HAZOP

(Lawley, 1974). In Hazop, a range of different keywords can be used to perform the keyword analysis (Tyler, Crawley, & Preston, 2000); facilities include the use of all, none, or part of the WMH or choose others where the WMH is not applicable in the context.

Sensitivity analysis

The fifth smart bit was the keywords used during the analysis of internal operations during Stage B2. These keywords were used to complete the qualitative sensitivity analysis, taking two opposing states of waste to identify the impact this waste has on the system. The approach was already context free in the original application; none of the elements were specific to nuclear or any context so could be transposed into the *Call Handling* context without further development.

Action evaluation grid

The sixth smart bit was the AEG. Evaluating the themed actions using the AEG during Stage C was largely unproblematic and required little development beyond the original application. The Call Handling Study was the first implementation of the method as part of WASAN outside of original context, but all of the elements from the AEG were well tested and so considered suitably generic before this use. The challenges that existed in Stages A and B in terms of operationalising the stage differently to the original approach did not exist for the AEG, as Stage C was operationalised in the same manner in *Call Handling* as in the original approach (a single focus group.) There was no option to conduct Stage C through individual interviews, as aggregating the results of individual AEGs would not lead to any meaningful results. Therefore, Stage C was operationalised through a focus group where key decision makers and representatives from the *Call Handling* system and technical specialists could jointly negotiate the ranking of each action against each predefined criterion. The structure of the focus group was largely based on MCDA (Jacquet-Lagreze & Siskos, 2001; Zionts, 1979) using qualitative criteria as described in the Call Handling Study. MCDA is well established and used in multiple contexts so the researcher had confidence that it would translate into the *Call Handling* context.

The one element which was context specific and did require development was the actual criteria used to judge the actions. The criteria from the original approach did not translate across to *Call Handling* (and nor did the researcher expect them too). Therefore, the criteria used for the AEG were identified during an interview with the Customer Contact Manager. In the interview the Customer Contact Manager was asked to identify attributes that an action identified in Stage B would need to possess for it to be implemented. To maximise legitimacy of the criteria, they were checked in two ways. First, as advocated by Keeney & Raiffa (1993), the criteria in the AEG were checked for completeness, operationality, decomposability, absence of redundancy, and minimum size. Once the criteria had passed these checks and the Customer Contact Manager was happy with them, they were shared with staff from *Call Handling* to check that they agreed that the criteria were sensible to judge potential actions against.

Higher authority signoff

The seventh smart bit was the higher authority signoff in Stage D; this remained broadly unchanged from the original approach. No elements from Stage D needed further development to make this applicable to *Call Handling* and it was deployed in the same manner as the original methodology. The only element that required a contextual decision was which higher authority to include in the stage. This is critical to the success of the approach as it aims to affect the upstream and downstream systems to reduce wastage in the system in focus. Therefore, if any actions affected any upstream or downstream systems under the control of the organisation, then the higher authority should include decision makers for both the system in focus and systems that will be affected by implementing any of the actions. We can use the notion of vertical recursion where the organisational structure is comprised of nested systems to understand who should be involved in the decision making process in Stage D. As shown in Figure 27, an action to avoid the waste entering the Level 1 System in Focus from the Level 1 Upstream System might have consequences for the Upstream System. The decision to implement the action cannot be taken at a Level 1 system as they do not have authority over both affected systems. The decision should be pushed to the higher level of authority at the Level 0 System. Therefore, the appropriate system to include in Stage D will depend on the context of the decision being made.

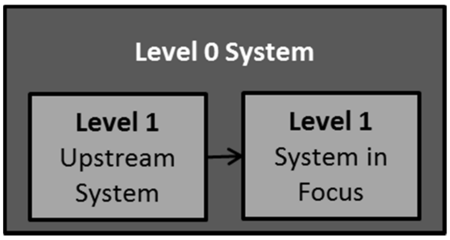

Figure 27 Diagram showing why sign off is needed from a higher authority

4.4.2 Assessing the generic applicability of WASAN

This section summarises the decomposition of the seven smart bits identified in WASAN. During the Call Handling study, the analysis identified that some of the smart bits (or their parts) required development before they could be applied to *Call Handling*, while some elements did not require any further development. The thesis identifies that the elements which should not be developed are those which translate the philosophy of WASAN into practice; these elements required constant replication across all applications of WASAN. If these elements are changed, then the approach is no longer WASAN; the fundamental assumptions of the new approach are different. The elements which require development are the contextual elements, and changing these elements makes the approach applicable to multiple contexts and therefore give an approach its generic qualities. Table 9 below identifies which elements are methodological (and therefore must be replicated in all WASAN applications) and which are contextual for each smart bit (and therefore will be adapted to the local context).

Smart Bit	Methodological Replication	Contextual Elements
Operationalizing WASAN	WASAN now has two modes in which Stages A and B can be operationalised: • Mode 1 is from the original approach where all participants are included in the same focus group for Stages A and B. • Mode 2 is where Stages A and B happens through individual interviews.	The most appropriate mode of operationalizing WASAN will depend on the context.
System Boundary	The elements required in a generic system definition of a system-in-focus are • The waste to be reduced. • The aims and purpose of the system in focus. • The channels into the system.	Two different broad categories of waste have been identified, these are • Tangible • Intangible
Keyword Analysis	The process of the keyword analysis is a key methodological factor for WASAN and needs to be replicated.	The actual keywords used in Stage B1 (analyse external operations) need to change depending on context.
WMH		The WMH keywords did not all work for intangible waste. Therefore, the keywords are context-dependant. It is likely that all keywords from the WMH can be applied to tangible waste, whereas only avoid and minimise are appropriate for intangible wastes. This requires further investigation in contexts with tangible and intangible wastes before it can be shown.
Sensitivity Analysis	The process of the sensitivity analysis is a key methodological factor for WASAN and needs to be replicated.	There were no contextual elements in the sensitivity analysis.
AEG	The process of the AEG is a key methodological factor for WASAN and needs to be replicated.	The evaluation criteria will change depending on the context. To ensure the criteria chosen are fit for purpose they should be compared with the 5 criteria from Keeney & Raiffa (1993).
Higher Authority Signoff	The process of the keyword analysis is a key methodological factor for WASAN and needs to be replicated.	Users need to use the notion of recursion to identify the lowest level system which encompasses all systems affected by the actions being evaluated.

Table 9 The methodological and contextual elements of WASAN

Table 9 shows how most of the methodological elements in the smart bits are those providing structure to WASAN; these structures and processes are what is required for a successful application of WASAN. The context-specific elements are those which sit around the structure, for example, who should be included in Stage D or which keywords are appropriate for Stage B1. Altering the contextual elements does not change that WASAN has been the approach used. It only seeks to make WASAN applicable to the context in which it is being applied. To ensure that the WASAN philosophy (identified in Section 2.6.2) has not been compromised during the development process in *Call Handling*. The next section will compare WASAN as applied in the Call Handling study to the WASAN philosophy identified from the original approach.

4.4.3 Philosophy of WASAN

During the implementation of WASAN in *Call Handling*, some elements were developed to make them generically applicable. This was necessary for WASAN to be applicable in the UK Police Force, and it was also required as generic applicability was identified as an attribute of PSMs. However, altering these elements might have changed the philosophy of WASAN identified in Section 2.6.2. If the philosophy of the approach has changed, then it could be argued that the approach used was not WASAN but some other approach. This would invalidate the claims that WASAN was generically applicable, which will have implications later when trying to assess if WASAN is a PSM. Table 10 lists the 18 statements that identify the WASAN philosophy and identifies if they are still relevant to the approach as used in *Call Handling*. The ID relates back to the statements from the Literature Review in Section 2.6.2; the identification of philosophy is how the statement of philosophy is transmitted through current WASAN methodology.

ID	Statement	Identification of Philosophy
1.	Waste has a negative impact upon a facility, but through formal thinking we can understand the behaviour of waste.	WASAN still structures the thinking of participants to understand the behaviour of waste.
2.	By understanding waste we can manage waste mal-operations and fluctuations that increase it and how it impacts a facility-in-focus.	Actions are still generated to manage waste and the impact it has on the facility-in-focus.
3.	Formal thinking can be extended to up/downstream of the facility-in-focus.	The impact of waste from upstream systems and on downstream systems can still be considered using WASAN.
4.	The aim of WASAN is to produce the best portfolio of high-impact actions to reduce the impact of waste on the facility-in-focus.	WASAN still aims to produce the best portfolio of actions to reduce waste.
5.	The actions should embrace the principle of ALARP.	The order of the WMH prioritises actions that are ALARP by considering avoiding before minimising. The AEG considers ALARP.
a.	Auditable- decisions can be traced back to source years later.	A clear audit trail makes it possible to see what decisions were made and why at each stage of the process.
b.	Transparent—the decisions and the process are understandable.	A clear audit trail makes it possible to see what decisions were made and why at each stage of the process.
c.	Clear—no misinterpretation of the content of discussions or the outcome.	All models are taken as a record of each meeting. Each model is validated by the interviewee/ participant. During the theming process, each model is verified to ensure the sensible and clear theming of actions.
d.	Strategic/planned—decisions are considered locally, but recognised within the wider strategy.	Stage C ensures actions are considered locally. Stage D considers actions in terms of the wider strategy.
e.	Managed—effective leadership of the decision-making process and delivery of actions.	Stage D assigns owners for each recommendation to ensure accountability for actions delivery.
f.	Optimised/minimised—a streamlined process which could be replicated.	Developing WASAN has not increased the length of an intervention using WASAN.
g.	Integrated—able to explore the wider waste-producing system.	Wider waste producing systems are explored in the external analysis by considering up/downstream systems.
h.	Delivered—a practical outcome of feasible recommendations.	Stage D assigns owners for each recommendation to ensure accountability for action delivery.
i.	Learning—building understanding of the wider waste-producing system.	WASAN focuses on participants learning about the waste producing system, specifically through structuring interviewees thought processes in Stage B and through sharing knowledge in Stage C.
ii.	Agreeing—negotiating the best agreeable outcomes from available insights.	In Stage C, staff is able to negotiate about the utility of each action in relation to the categories in the AEG until they come to an agreement.
iii.	Facilitation—providing structured support to stakeholders' analysis, learning, and negotiation.	All stages are implemented with a facilitator.
iv.	Usable—the method is usable by novice facilitators/practitioners, essential for national roll-out.	The stages are no more complicated than in the original approach.
v.	Systemic analysis—rigorous analysis of system's far-reaching interrelationships.	WASAN considers the interrelationships with wider systems from the system in focus both vertically in Stage D and horizontally in Stage B.

Table 10 Showing the WASAN philosophy has not been compromised during the development process

Table 10 shows that all elements comprising the original philosophy of WASAN are still present after developing WASAN to make it more generic. This shows that the approach used in Call *Handling*—and subsequently in *Switchboard, Crime Admin, and Crime Desk*—was still WASAN as it translated the WASAN philosophy into practice. If the developments had compromised the ability of the approach to translate the stated WASAN philosophy into practice, then the approach used could not be considered WASAN. For example, if the approach no longer considered the impact an upstream or downstream system had on operations then we could say that Statement 3 was not fulfilled and therefore the approach used no longer exhibited the same ontological position as the original WASAN and therefore could not be considered the same approach.

4.5 Evaluation of development of WASAN and Discussion Points

The above section has shown how through theoretical and practical development WASAN is now applicable in multiple contexts. Developing the approach from a bespoke methodology applicable only in nuclear contexts to one that could be applied in *Call Handling* at a UK Police Force has developed the generic properties of WASAN. The new generic applicability of WASAN has implications for the inclusion of WASAN as a generic PSM. Along with this, there is wider knowledge of PSMs, development of methodology using smart bits, and the interplay between rigid methodological replication and contextual elements. This learning is developed into discussion points to be revisited in the Discussion Chapter.

Analysis of WASAN identified elements that would not translate into contexts beyond nuclear. To simplify the development process, WASAN was split into a set of smart bits that could be analysed and developed in isolation. This minimised the chance that development of one part of WASAN would have unintended consequences for other parts. The first smart bit requiring development was the mode of operationalising WASAN in Stages A and B. WASAN was originally deployed in a focus group; however, this was not practically or politically feasible in the Police context. The approach was developed to accommodate individual interviews. Each Stage B interviewee based their analysis on the same definition of the system in focus developed in a single Stage A interview; this ensured consistency across all Stage B models. The second element requiring development was the system definition in Stage A. Many elements required in a systems definition were scaled back as much of this from the original was only relevant to nuclear. The critical elements in a system definition for Stage A now include the system in focus, the waste to be reduced, the aims and purpose of the system in focus, and the channels into and out of the system. The definition of waste was expanded to include intangible wastes. The broader definition reflected the new found understanding that waste could take many forms beyond the narrow definition from nuclear. In *Call Handling*, the waste analysed was time which fell outside of the original definition of waste, but was included within the updated definition. The third element was the keywords used from the WMH during Stage B1. Most of these were not applicable in the new context as the nature of waste changed from tangible to intangible. Only ‘avoid’ and ‘minimise’ were successfully applied to the intangible wastes by participants in the Call Handling Pilot; ‘recycle’, ‘recover’, and ‘dispose’ did not conceptually or practically work with an intangible waste and so were excluded from the Stage B1 keyword analysis. The fourth smart bit is the AEG, which as a process was transferable to the new context; this was expected as the AEG was broadly based on existing well defined and generic tools such as MCDA. The criteria used in the AEG to judge actions needed to be developed as the criteria from nuclear were not relevant. To test if the new criteria were appropriate, the five checks from Keeney & Raiffa (1993) were compared with the criteria proposed for the AEG. These were completeness, operationality, decomposability, absence of redundancy, and minimum size. The final smart bit considered is the higher authority sign off. This too was transferable; however, to understand which authority was required in signoff, we drew from the vertical recursion. Where the implementation of an action might affect multiple systems, the lowest level of recursion responsible for both systems should be consulted as they could assess if the upside in one system was worth any downsides in other affected systems.

This project has shown how the notion of smart bits has been used to develop WASAN for use in nuclear and then continue the development process further so WASAN can be considered generic. This type of development has potentially wide-reaching uses within PSMs and OR, either in the development of new approaches or one-off interventions. Smart bits could be used to combat some of the negatives associated with multimethodology. Mulitmethodology is the practice of linking or combining different methods or techniques together (Munro & Mingers, 2002). It has been advocated because real world problems tend to be multidimensional; thus, the ability to combine different techniques together to address the different dimensions of a problem can make the approach more adept at dealing with the full richness of the real world (Franco & Lord, 2011). However, mixing methods and techniques also mixes the philosophies underpinning them. "Mixing methodologies arbitrarily becomes bogged down in incommensurabilities, inconsistencies and incoherence" (Schwaninger, 2004 p.412) and the philosophy of the resulting approach is unclear. Smart bits allow the mixing of techniques under a single coherent philosophy, as demonstrated in WASAN. Therefore, *Discussion Point 3 considers if smart bits can be used by developers of OR approaches to combine methods without mixing philosophies.*

During the development of WASAN to a generic approach, the project identified methodological replication and contextual elements as important factors in discerning if an approach is widely applicable. The methodological elements are those which need to be replicated in each intervention to say the approach in question has been used. These are the elements that translate the philosophy into practice. In addition to these elements, contextual elements need to adapt depending on the context; these help to adapt an approach to the given context, thereby making it applicable to the specific requirements of the users—for example, the evaluation criteria of the AEG needs to fit with the value set of the users, else final actions will not be implemented. The contextual elements are the bridge between the methodological elements and the context. *Discussion Point 4 considers if for an approach to be generic it must have methodological elements which are replicated regardless of context and contextual elements which adapt the methodology to the context.*

This section has successfully shown WASAN as a generic approach applicable in multiple contexts. WASAN was successfully deployed in *Call Handling*, and was used a further three times in the UK Police Force. In the three further uses, none of the methodological elements required further development, so the philosophy of WASAN was translated into practice through the methodology. This section has presented the data to answer RQ2: *"How can PSMs be developed into suitably generic approaches applicable in multiple problem contexts?"*. The answer to this question will be considered alongside the discussion points in the Discussion Chapter.

4.6 Application of the four pillar framework

This section focuses on RQ3: *"How can an approach show it has the defining features of PSMs?".* To test how the framework can be operationalised, it is applied to WASAN to understand if it demonstrated the defining features of PSMs. This section works systematically through the 15 questions from the four pillar framework and assesses WASAN to see if the features from the framework can be identified both practically and philosophically. To understand if WASAN demonstrates these features practically, this section examines the Call Handling

Study in Section 4.3 to identify the features from the four pillar framework. To understand if these features are ingrained in the philosophy of WASAN, Statements 1–5, a–h, and i–v that describe the philosophy of WASAN from Section 2.6.2 are examined for their presence. When referring to Statements 1–5, the full quote will be given. For a–h and i–iv, only the main word followed by a description to contextualise the word is given. These statements only relate to ontology, epistemology, and axiology; therefore, the final pillar 'Structured Analysis' is justified based solely on experience and learning from the Call Handling study. As in Section 2.4, where the four pillar framework was applied to five established OR approaches, many of these questions are not problematic to answer and therefore have relatively short answers.

4.6.1. Pillar 1: Systems characteristics

1. Does the approach draw an open boundary around the system?

In WASAN a system boundary is developed during Stage A. The system boundary [Figure 28] includes the Channels In and Out of the system-in-focus. There is also recognition of Upstream and Downstream systems. This system boundary fits the descriptions of open system boundaries by Checkland (1981 p.312) where an open system is where the boundary is "the area within which the decision taking process of the system has power to make things happen, or prevent them from happening".

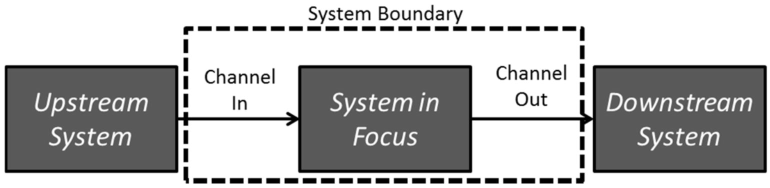

Figure 28 Open system boundary for WASAN

The WASAN philosophy also points to an open boundary. Statement (3) says, *"Formal thinking can be extended to upstream and downstream of the facility-*

in-focus" Extending the formal thinking beyond the system-in-focus recognises that the system-in-focus can be affected by elements external to the system boundary; therefore, the system boundary is open.

Overall, WASAN clearly defines a system using an open boundary where elements from outside the system boundary can effect what is considered within the system boundary.

2. Does the approach acknowledge there are systems at different hierarchical levels to the one being modelled?

There is an explicit use of hierarchy built into WASAN; during the Call Handling Study participants were included from different hierarchical systems throughout the intervention. Table 11, adopts Jackson's (2003) Level 1, Level 2, and Level 0 to distinguish between the system levels used during each WASAN stages to maximise legitimacy of action and increase buy-in to the final proposals from across the organisation.

Stage	System	Hierarchical Level	Purpose
Stage A	Customer Contact	Level 0	To define the *Call Handling* System
Stage B	Individual Call Handlers	Level 2	Participants to analyse the operations of the system
	Call Handling	Level 1	Composite model of data representing *Call Handling*
Stage C	Call Handling	Level 1	To represent *Call Handling* during action evaluation
	Customer Contact	Level 0	To represent Customer Contact during action evaluation
	Incident Resolution	Level -1	To represent Incident Resolution during action evaluation
Stage D	Customer Contact	Level 0	To evaluate the recommendation in relation to wider system goals

Table 11 The use of recursive hierarchies in WASAN

Hierarchy is also recognised in the WASASN philosophy. In WASAN, decisions should be strategic/planned—(d) implying that decisions are considered not only locally, but also considered within the wider strategy that will come from higher order systems. Secondly, there should be systemic analysis (v) implying that there is analysis of the system's far-reaching interrelationships.

WASAN certainly acknowledges that there are systems at different hierarchical levels to the one being modelled and structures this into the research design.

3. Does the modelling approach seek to manage complexity?

Complexity is managed in WASAN by understanding the emergent system properties arising from the impact of waste upon system behaviour. Emergent properties with negative consequences for the system arising from waste entering the system should be reduced through the analysis of operations in Stage B. These actions are then codified and themed in a model to hold onto the complexity; thus, each themed action can be considered in the AEG.

Philosophically, WASAN considers complexity in Statement (1) "Waste has a negative impact upon a facility but through formal thinking we can understand the behaviour of waste"; in Statement (2) "By understanding waste we can manage waste mal-operations and fluctuations that increase it and how it impact a facility-in-focus"; and, in Statement (3) "Formal thinking can be extended to up/downstream of the facility-in-focus". These show that philosophically WASAN does not aim to eliminate complexity using reductionist techniques, but seeks to capture complexity through formal thinking to understand emergent system properties.

4. Does the approach model an identifiable system?

WASAN has a specific modelling language that seeks to frame the system in focus as a waste-producing system with specific elements, as defined in Stage A. The language and the meaning attached to it (such as upstream system and avoidable waste) is unique to WASAN and therefore show WASAN as an approach that models a specific system.

The system to be modelled is identified in the WASAN philosophy Statement (1): *"Waste has a negative impact upon a facility but through formal thinking we can understand the behaviour of waste"*; this shows that the system is focused upon waste. Statement (2)—"*By understanding waste we can manage waste mal-operations and fluctuations that increase it and how it impacts a facility-in-focus"*—this shows that WASAN seeks to understand the behaviour of waste and how this impacts a specific system. Finally Statement (3)—" *Formal thinking can be extended to up/downstream of the facility-in-focus"*. This shows that the identified system includes analysis of other elements upstream and downstream of the system in focus.

4.6.2. Pillar 2: Knowledge and involvement of stakeholders

5. Does the approach build a qualitative model?

All the models built in WASAN are qualitative in nature, thereby representing the system and its interrelationships through words and pictorial representation. In Stage A, the model representing the system definition and wastes are written descriptions. In Stage B, the keyword analysis is built in a tabular format with written descriptions of the waste, its properties, and how it can be managed internally and externally. In Stage C, the AEG is similar to a qualitative MCDA.

Philosophically qualitative models aim for participants to learn (i) about a problem and the interrelationships between systems through a systemic analysis (v).

6. Can the approach build a model in a facilitated way?

In WASAN, all stages A–D are supported by a facilitator who takes the descriptions and thoughts of the participants and interviewees and structures them into the models that are developed in WASAN.

Facilitation (iii) is included in the WASAN philosophy, where facilitation provides structured support to stakeholders' analysis, learning, and negotiation.

7. Does the approach focus on participants learning about the problem?

WASAN encourages participant learning in two ways. First, WASAN frames the problem differently to how participants would usually think about it. Many interviewees commented on how they usually did not think about Call Handler time in the manner that it was framed in the interviews. This was most apparent in Stage B during the one-on-one interview. Second, in Stage C, knowledge and learning was shared among participants of the focus group. Senior managers were not always aware of the issues faced by Call Handlers and so gained insight into some of the problems encountered by them on a daily basis. Participants also learnt from the technical specialists who provided expert input on a few technical matters during the focus group. Finally, the Call Handlers were able to see how the senior managers viewed the issues presented to them and learn more about the wider objectives for *Customer Contact* and how they were contributing to wider organisational goals.

Philosophically, WASAN aims for participants to learn (i) and build an understanding of the wider waste-producing system. Participants should also learn by sharing knowledge during negotiations before agreeing (ii) on outcomes.

8. Does the approach aim to produce politically and culturally feasible solution over optimal solutions?

WASAN aims to produce politically and culturally feasible solutions by enveloping a range of participants in the process. Buy-in was generated with staff from *Call Handling* as they were widely consulted to generate actions which were fed to management. This produced political will to implement action among Call Handlers. Senior decision makers were included during the convergent thinking phases in Stages C and D. In Stage C, the decision makers are supported by technical specialists, who were be able to clarify any points of contention along with staff from *Call Handling,* who gave their perspective, as decision makers were not always 100% familiar with how the issues being discussed were presented on the ground. Finally, in Stage D the final decision making authority is included so that any decisions made involved the people and gave them the power to agree with the actions and see that they were implemented.

Philosophically, WASAN aims to produce actions which are likely to be implemented by building political and cultural feasibility. This is done through learning (i) about the problems, which builds understanding in powerful stakeholders who are therefore more likely to take action. Actions are agreed upon (ii) through negotiation, where the best agreeable outcomes are developed based on available insights. The process should be managed (e) through effective leadership and should lead to recommendation that can be delivered (h) as they are practical and feasible.

4.6.3. Pillar 3: Values of model building

9. Does the model reflect the different social realities of the participants?

The 11 Call Handlers interviewed during Stage B each analysed the system according to their own social reality. While Stage A sought to ground Stage B interviewees' perceptions firmly within a shared boundary, each participant drew on their own unique experiences, knowledge, and perspective of *Call Handling* during their interview. Each of these social realities was included within the themed actions, which were evaluated using the AEG.

Philosophically, the different realities are incorporated into the model through facilitation (iii). The individual and composite models are built by a facilitator who ensures all perspectives (and actions) from the individual models are represented in the composite model.

10. Is the model building process suitably generic so it can be transferred to multiple problem contexts?

Section 4.4 was concerned with showing the generic applicability of WASAN. As discussed in the section, WASAN was developed in *Call Handling*. This identified the elements which should be kept the same and replicated across all WASAN interventions and those elements which are flexible depending on the context. Based on the application of WASAN in a new problem context and the successful use of WASAN in *Switchboard, Crime Admin, and Crime Desk*, WASAN can be considered generic enough to be applicable in multiple contexts.

11. Does the approach rely on showing procedural rationality to give reliability to outcomes?

WASAN cannot show that recommendations are substantively rational, as there are no objective criteria to compare actions against or prove that the best set of actions have been found. However, WASAN does aim to show that actions have been obtained by following a logical procedure. That procedure is publically stated and can be defended against if required.

Philosophically, WASAN shows rationality in the procedure by being clear (c) and transparent (b) in the methodology. The aim of WASAN is stated in Statement (4): "*The aim of WASAN is to produce the best portfolio of high-impact actions to* *reduce the impact of waste upon the facility-in-focus".* Actions are judged against Statement (5), which states that *"Actions should embrace the principles of ALARP".*

12. Does the model build a validated audit trail of the decision making process?

The audit trail for WASAN is threefold. First, the model built during each stage or sub-stage (in the case of individual interviews) is validated by the participants at the end of the interview. The model acts as a formal record of the meeting and data collection. This was formalised in Stages A, B, and D, where a written document summarising the definition (Stage A), actions (Stage B), or recommendations (Stage D) was sent to the participants to validate after the interview. In Stage C, all rankings were shown to participants at the end of the focus group to ensure that they had final agreement on the placing of actions. Second, during the theming process between Stages B and C, all maps theming the wastes and actions were validated by a Control Room Supervisor to ensure the sensible grouping of results. Third, all decisions were recorded in a formal audit trail. The outputs from each stage are the inputs for the next stage. These can easily be recorded as a full end-to-end audit trail. Fourth, the decisions and audit trail are taken to the higher order system for sign-off on any actions, thereby ensuring that the process and decisions are agreed upon by the system owners.

Philosophically, WASAN aims to be fully auditable (a) where decisions can be traced back to the source. In addition, the audit trail and decision process should be transparent (b) and clear (c), so the decision process is understandable and not misrepresented.

4.6.4. Pillar 4: Structured analysis

13. Does the approach structure knowledge through different stages of analyses, i.e. is it a methodology?

There are clear stages in WASAN. The stages are completed in order from Stage A through Stage B; Stage C finished with the final recommendations and the program of work at the end of Stage D. Each stage represents a different phase of analysis, thereby incorporating different methods and techniques into the WASAN methodology. Therefore, WASAN is a staged methodology.

14. Are there distinct phases for divergent and convergent thinking?

WASAN is structured around four Stages (A–D), in which there is divergent thinking followed by convergent thinking. Stage A sets the boundary of the system being analysed. When interviewees are encouraged to think creatively and divergently about the problem, the boundary from Stage A provides them with a clear focus, so they do not go ‘off track’ with their thinking. Stage B is the divergent thinking phase, where participants are encouraged to think divergently about the problem of waste impacting the system-in-focus and generate potential actions to reduce the impact of the waste. In *Call Handling*, as interviews were held one-on-one, the individual actions were themed into a composite model. In this model, actions from different interviewees that were the same or very similar were themed into one action to reduce the volume of actions to be evaluated in Stage C. While this process reduced the number of actions from 157 to 76, it is not a convergent thinking phase as no ideas are lost; they are only condensed into a more manageable form. Stage C marks the beginning of the convergent thinking phase. Actions are evaluated in the AEG to sort actions into low priority, medium priority, and high priority. Doing this implied that low priority actions could be discarded in favour of focussing on the higher priority actions. Stage D represents the final stage with further convergence to a set of actions that are deemed to have the highest impact and are politically feasible in accordance with the wider organisational goals.

15. Does the approach manage knowledge through the methodology to avoid 'Knowledge Leaks'?

In *Call Handling*, the Police were keen to have a clear and transparent audit trail of decision making to show accountability in their decisions. Therefore, an audit trail was produced to show how each individual action and waste was themed, how these themed actions were rated in the AEG, and what final decisions were made during Stage D in relation to whether the action should be implemented. This clear follow through from one stage to another shows that there are no knowledge leaks by design and thus minimised knowledge leaks to only human error. All candidate actions can be followed through the process from idea generation to decision. This is made possible as the output for each stage is the input for the next stage. This process is shown in Figure 29.

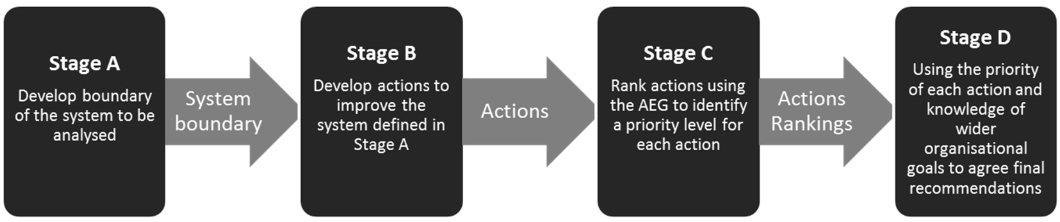

Figure 29 Minimising knowledge leaks in WASAN

The clear audit trail and link between outputs and inputs for each stage of analysis means that knowledge leaks are minimised throughout the WASAN process.

4.7 Evaluation of the application of the framework and Discussion Points

This section has shown that WASAN shares the same common features as PSMs identifying each of the common features of PSMs identified in the four pillar framework within WASAN. For all questions 15 in the framework, WASAN could show practically through the Call Handling study that it has the features required to be considered a PSM. Further, in relation to ontology, epistemology, and axiology, WASAN was able to show that it possesses the features from the framework at a philosophical level. Therefore, through comparison with the four pillar framework, this project has the data to answer RQ3 *“How can an approach show it has the defining features of PSMs?”* by confirming that all the defining features of PSMs are found it WASAN. The answer to RQ3 will be considered in the Discussion Chapter.

The application of the four pillar framework on WASAN proved useful to show that WASAN shared the same features as PSMs and therefore strengthens the case for its inclusion alongside the existing set of PSMs. However, the framework has implications beyond WASAN. *Discussion Point 5 considers if the four pillar framework can be applied to other fringe PSMs to strengthen their case for inclusion alongside the existing set of PSMs.*

4.8 Summary of Findings 1

The findings from this chapter have shown how bespoke approaches can be developed into generic approaches by identifying the elements which require constant replication and the elements which need to adapt based on context. Identifying these two classes of elements provides a deeper understanding of how future approaches could be developed so that they can be considered generic. Second, this chapter has shown that WASAN demonstrates the defining features of PSMs both practically and philosophically. The next chapter of this thesis will focus on the contributions WASAN can make to the theory of PSMs. It is suggested from these findings that WASAN shares a common underpinning framework with PSMs and therefore theory development linked to that framework will be applicable not only to WASAN but also the existing set of established PSMs.

Chapter 5

Findings 2: Modelling the expanded system

5.0 Introduction

This thesis seeks to critically examine the philosophical, theoretical and methodological features of PSMs. This chapter contributes to this analysis by identifying a new contribution to the framework of WASAN and model building. The findings from this thesis so far have identified a common framework of features of PSMs. These features are a manifestation of the philosophical assumptions which underpin PSMs. This chapter presents the transferable contribution WASAN makes to the underpinning philosophical framework of model building in PSMs. This contribution is later considered in the wider PSM context in Section 6.4 in the Discussion Chapter. The analysis of this approach to model building within WASAN will answer RQ4 "*Can philosophical, theoretical and methodological contributions identified in one PSM be shown as relevant in others, thus showing a common framework?*".

5.1 Expansionism

The contribution identified in this chapter seeks to understand how modelling multiple linked systems can lead to additional benefits to decision makers. Ackoff (1979) advocated the doctrine of expansionism, where understanding of a system and its purpose is based on how the system-in-focus helps to fulfil the goals of its expanded system. Ackoff (1979) contrasted this with reductionist thinking where knowledge and understanding of a system is derived from taking the system-in-focus apart and understanding the individual elements of that system. For example in expansionist thinking the definition and purpose of a car should be derived from the larger transportation system instead of trying to define the purpose of a car based on the components such as an engine and a steering wheel. The expanded system definition of the car would give a much richer understanding of what a cars purpose is as the definition could draw from transportation networks, roads and the use of these elements. A reductionist definition of a car would miss these elements instead focussing on what an engine does and what a steering wheel does. To learn more about waste production in *Call Handling* using expansionist thinking would require the modelling of the elements surrounding *Call Handling*. These individual elements could then be considered together. This allows users to gain a meta-systemic understanding of the waste producing system meaning actions can address problems across the meta-system rather than focussing on problems in isolation.

To successfully gain further understanding about *Call Handling* through expansionism the project first had to identify how the expanded system should be defined. The first definition of the expanded system was derived based on concepts drawn from VSM (Beer, 1981) where it is assumed systems are arranged in a hierarchy of nested systems. That is each and every system is one sub-system contained within a higher order system and in turn is comprised of multiple sub-systems each also comprising of multiple nested sub-systems. In the Call Handling study this would mean understanding the generation of waste within *Call Handling* by modelling the higher order *Customer Contact System* [Figure 30]. However modelling the *Customer Contact System* using WASAN would present challenges to understanding the impact of WASAN on *Call Handling*.

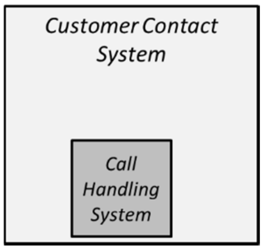

Figure 30 Vertical hierarchy of Customer Contact

WASAN models of both systems are not suited for comparison. At best comparing models of these two systems would identify vertical dependence between the systems. Understandings vertical dependence does not fit with the WASAN philosophy, as WASAN does not consider the flow of waste as vertically dependent but horizontally dependent. Therefore inspiration for defining the expanded system is taken from how WASAN models a system and views dependence from other systems. Figure 31 represents the required elements in a WASAN Stage A system definition, it shows how the Channels In and Channels Out of the system link the system-in-focus to the surrounding upstream and downstream systems with the surrounding systems represented as black boxes. Beer (1979) used the concept of black boxes to represent the systems surrounding the system-in-focus in VSM. This limits the boundary of analysis to a single system, thus we can identify things entering the system from a black box and try to understand how these things affect our system-in-focus but do not need to expand the boundary of analysis to include the black box. In VSM if a greater system understanding was required it would be possible to model the vertical black box and expand the boundary of analysis. For WASAN instead of expanding the system vertically it is more coherent with the approach to expand the system horizontally, modelling the upstream and downstream systems. This is because WASAN views interdependency horizontally across systems so this element should be captured within the expanded system. Modelling individual systems upstream and downstream from the original system-in-focus using WASAN should lead to greater understanding of the horizontal dependence across systems in the expanded system. This should lead to a meta-systemic understanding about the behaviour of waste and how it moves through the expanded system embracing the doctrine of expansionism. The aim of this is to show that additional knowledge about waste and system behaviour can be derived from understanding the relationship between linked WASAN models. That is there are emergent properties of the meta-system that can be understood by looking at the expanded system which cannot be seen from a single WASAN model viewed in isolation.

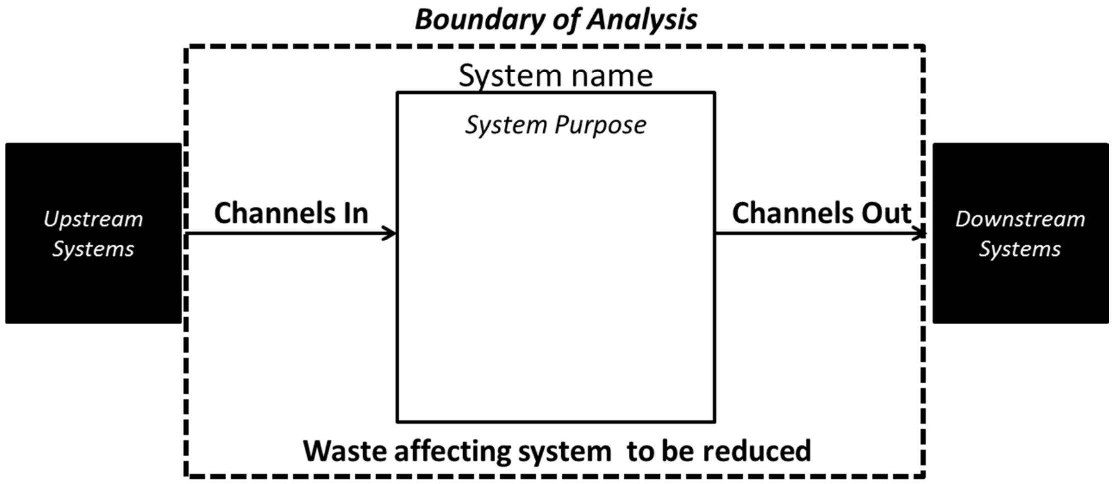

Figure 31 Generic Stage A system definition

The gap identified in this chapter will make a contribution to PSM theory and methodology by showing that modelling horizontally dependant systems expands the knowledge about all modelled systems by capturing the emergent properties of the meta-system. PSMs are normally constrained by a system boundary which focusses the analysis on a specific system or topic. When multiple related systems have been modelled combining the models to analysis the horizontal dependency across systems brings an additional layer of information for decision makers that could otherwise not be captured.

This chapter first presents the Further Study which shows the individual modelling of three additional systems within *Customer Contact*. These three systems all sit on the same horizontal plane as the *Call Handling system* and therefore have horizontal dependence with another. By modelling these three systems in addition to the *Call Handling system* the project identified the potential benefits to be had by analysing the system at the expanded system level. This type of analysis is new for WASAN and PSMs in general and so is identified as a gap in knowledge. The gap is closed in practice when new modelling approaches are used to build these expanded system models which are able to identify the interrelationships and interdependencies relating to waste production across the meta-system. Three criteria are identified as being required in the individual models for them to be successfully combined. The practical concepts from this findings chapter are then identified as further discussion points which are to be considered in relation to broader theory in the Discussion Chapter of this thesis.

5.2 Further Study

This section builds on the Call Handling Study from Section 4.3 by presenting the use of WASAN in three further systems at the UK Police Force: *Switchboard*, *Crime Desk* and *Crime Admin*. After the final analysis of *Call Handling* the force were keen to identify efficiency gains in the units surrounding *Call Handling* using WASAN. For the researcher this was seen as an opportunity to learn more about WASAN through further applications of the approach. For the Police Force WASAN was seen as a way to independently review each unit. Each system was modelled and analysed separately and as such in total there were four full and separate applications of WASAN within the UK Police Force.

The further study had two aims: first, to understand if individual level models can be combined to show the horizontal dependence present in an expanded system; second, understand if following the doctrine of expansionism lead to additional learning beyond that of the individual single systems. That is, does expanding the system lead to greater knowledge about the interrelationships between models than if the systems are considered individually in isolation? The presentation of the further study below is organised into two parts: first, the development of the individual level models; second, building the expanded system models.

5.3 Development of individual models

This section presents the development of the three individual models of *Switchboard*, *Crime Desk* and *Crime Admin*. The development of these models is ordered by stage of analysis. The further study is presented sequentially by WASAN stage moving through Stages A–D drawing from each of the three applications as necessary. This is done to reduce repetition and for ease of making comparisons between the modelled systems. This is also reflective of the learning process, the new insights from the further study were as a result of considering all applications together rather than specific learning points being attributed to specific applications of WASAN. While the three studies are presented together the data collection and initial analysis for each system was performed in isolation from the other systems.

5.3.1 Mode of WASAN

The first decision required for each system was which mode of WASAN to use. Mode 1 is the original approach used by Shaw & Blundell (2010) where data is collected in a focus group for all stages, this leads to joint definitions of the system boundary in Stage A and joint identification and analysis of sources of waste in Stage B. Mode 2 was applied in the *Call Handling system* where a single system boundary is identified in Stage A by the system owner. In Stage B individual interviews are held with candidates' responses aggregated to create a composite Level 1 model of the system-in-focus. These aggregated (themed) actions are taken forward to Stage C for evaluation by a focus group. As with the Call Handling Study for pragmatic reasons surrounding the abstraction of staff and for methodological consistency across each application the further study used Mode 2 of WASAN.

5.3.2 Stage A

The aim of Stage A is to define the system boundary of each unit. The system boundary is comprised of three elements: the waste to be reduced; the system purpose; and, the Channels In and Out of the system to be included in the analysis. These are reported below along with the selection of Stage A participants.

In the further study a single Stage A interview was conducted with the owner of each system-in-focus. In *Crime Desk* and *Crime Admin* the system-in-focus owner was the primary interviewee as they had authority to agree the scope and boundary of the system. They were supported by a secondary interviewee who had a greater operational knowledge of the system [Table 12].

System	Primary interviewee	Secondary Interviewee
Switchboard	Control Room Supervisor with responsibility for Switchboard	N/A
Crime Desk	Force Crime Registrar	Crime Director
Crime Admin	Force Crime Registrar	Crime Administration Manager

Table 12 Participants in Stage A of the Further Study

The first element required in the system definition was identification the waste to be reduced. The UK Police Force had agreed to the use of WASAN in the further systems on the basis of identifying ways to reduce wasted time in each system. Therefore time was agreed as the waste to be reduced in all three systems.

The second element required in the system definition is the system purpose. In *Switchboard* this came purely from documentation (role profile for *Switchboard* Operator). The reliance on documentation for the system purpose was twofold; first, the documentation used had recently been revisited and updated by the force to reflect the duties of *Switchboard* so it had legitimacy with staff and management; second, the Control Room Supervisor had only recently taken responsibility for *Switchboard* so did not have as wide reaching knowledge of the system as the Customer Contact Manager did of *Call Handling*. Therefore they felt more comfortable relying on the existing documentation. The *Switchboard* Stage A interview served the purpose of checking the role profile was sufficient as a definition of system purpose, shown below.

Switchboard

Main purpose of the role:

Operate the central switchboard, answering all calls, establishing information, evaluating and deciding upon the callers requirements and actioning as appropriate, in order to ensure that the caller receives a prompt, courteous and helpful response.

Main responsibilities:

Operate the central switchboard and answer all external/internal telephone calls to the [Police Force], ensuring that the caller receives a prompt, courteous and helpful response. Ascertain essential information from the caller, evaluate, decide and action as appropriate, in order to direct the calls to the correct person/location to satisfy the particular needs of the caller. Provide a wide range of advice and information to callers, which helps to resolve their reason for calling [the Police Force]. In some circumstances this may involve directing callers to other more appropriate organisations. Update the computerised switchboard database in respect of personnel movements and changes of telephone numbers, ensuring that the accuracy of the directory is maintained at all times. Update room notice board and records on daily basis to show temporary and permanent changes to extensions, including special operations. Report system faults to outside agencies as requested whilst continuing to maintain service. Ensure integrity, fairness and *consideration of the needs of others are incorporated into the daily duties and relationships with colleagues. Reply to emails from the public in a timely, helpful and courteous manner.*

For Crime Desk the Crime Director took the lead in defining the purpose of the system. The Force Crime Registrar agreed the definition and gave authority for it to be used in the Stage B interviews. In *Crime Admin* this same process was followed with the Crime Administration Manager defining the system purpose. These two system purposes are below:

Crime Desk

Crime Desk Investigators take reports of volume crime from the public over the phone and carry out low-level investigations to fill out the C1 crime reports in accordance with force policy. C1s are then reviewed by a Crime Director who ensures all required information is recorded and crimes are categorised correctly, the Crime Director then makes a decision on whether to continue with further investigations. The Crime Desk is also responsible for the monitoring of PNC bring ups, initial investigations for low risk forecourt watch bilkings and being a contact point for any current crime updates to the public. The force Volume Crime Manager owns this system.

Crime Admin

The Crime Admin function take completed C1s and amendment forms and inputs them to the electronic database so the relevant information can be used for research, information tracking, statistics and analysis across the force. They also input information onto the miscellaneous filing system. They file and retrieve crime reports across the organisation, send correspondence to victims with updates about a crime including information about cautions, reprimands or warnings given to offenders. They manage requests for information from insurance companies, take *internal phone calls for updates on crimes or statistics. Manage request for information from criminal injury compensation and put retention duties on a crime file as per force policy.*

The third element required in the system definitions were the Channels In and Channels Out of each system which were to be included within the analysis [Table 13]. The channels included in the analysis are those considered a source of major potential waste, this focusses the analysis to the most meaningful areas where the biggest savings are most likely to be found. Each of the systems had one primary channel where the major waste was generated and secondary channels which generated less waste but which the system owner also warranted inclusion within the analysis. For *Crime Desk* and *Switchboard* the primary channel in was phone calls. The primary channel in for *Crime Admin* was Crime Reports (C1 and C1a forms). Crime Reports are submitted by Officers and *Crime Desk* staff to *Crime Admin* who are responsible for inputting data from the paper forms into electronic databases for recording purposes. However the forms are not always filled out correctly at source which leads to an increase in processing time. This made the C1 forms a suitable channel for waste to be analysed by WASAN. The change from analysing phone calls as the primary Channel In to crime reports represented another significant change in how WASAN was used. While WASAN had been proven to work on phone calls the processing of forms was a very different type of channel than speaking to a person on the other end of the phone. This therefore tested the applicability of the analytical smart bits in Stage B.

System	**Switchboard**	**Call Handling**	**Crime Desk**	**Crime Admin**
Primary Channel In	Phone Calls	Phone Calls	Phone Calls	Crime Reports
Secondary Channels In	Emails			Phone Calls
				Emails

Table 13 Primary and secondary Channels In to each modelled system

These three elements were then combined to provide a system definition for each system which identified the boundary and scope of the system to be analysed [Figure 32]. This system definition was carried forward to focus the analysis of the system in Stage B.

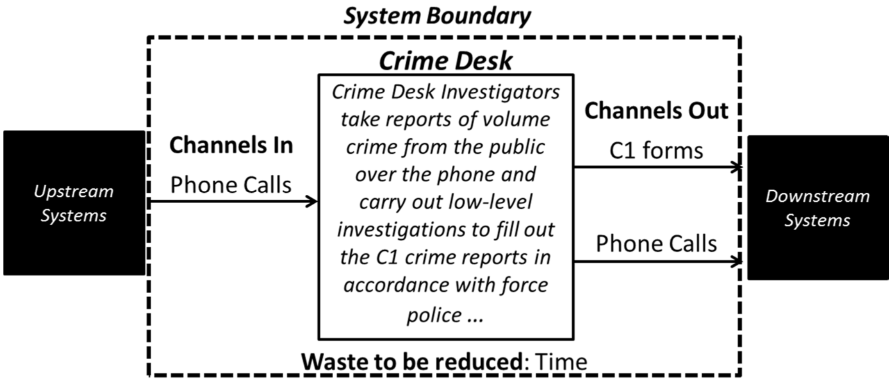

Figure 32 Crime Desk system definition

5.3.3 Stage B

The purpose of Stage B is to analyse the internal and external operations of the system-in-focus. As with *Call Handling* the interviews were conducted one-on-one using a single system definition from Stage A. The interviews for each system were then aggregated at the end to give a Level 1 model of the system-in-focus. The number of Stage B interviews for each system [Table 14] were lower than in *Call Handling*. This was for two reasons: first, each unit was significantly smaller than *Call Handling* so fewer interviews were needed to cover a similar proportion of staff; second, constraints from the Police Force gave a shorter timeframe to conduct and analyse the interviews than in *Call Handling* therefore for pragmatic reasons the number of interviews has to be lower than in *Call Handling*. The number of interviews for each system was agreed with the system owner from Stage A, this took into account the need to balance the time constraints and the need for a representative sample size. While a greater number of Stage B interviews in each of the further systems may have generated more sources of waste and more actions the researcher does not think the smaller sample size affected the integrity of the models nor the ability to draw theoretical and methodological findings about WASAN and PSMs. That is there was sufficient theoretical saturation for the research to achieve the aims of the further study.

Unit	FTE in system	Number of Participants
Switchboard	8	5
Call Handling	52	11
Crime Desk	16	4
Crime Admin	12	4

Table 14 Number of Stage B interviewees from each system

In the further studies the keyword analysis of internal and external operations replicated the approach used in *Call Handling* as it was a methodological process required for WASAN. The two keywords 'avoid' and 'minimise' were successfully applied in all systems including *Crime Admin* where the Channel In (C1 and C1a forms) was substantially different to the other systems where the main Channels In had been phone calls. In each system interviewees were able to identify sources of waste and using the keywords analysis identify potential actions to reduce the impact of the identified sources of waste. The individual candidate actions were themed to create a single model and set of actions for each of the analysed systems. The total sources of waste and actions for each system as generated by the interviewees are shown in Table 15. Also included is the number of wastes and actions after similar interviewee responses within one system were themed to reduce the data to be considered in Stage C. As with *Call Handling* the themed sources of waste and themed actions were taken forward to Stage C for evaluation.

Model	Theming	Sources of Waste	Action
Switchboard	Candidate	25	53
	Themed	14	24
Call Handling	Candidate	44	156
	Themed	17	76
Crime Desk	Candidate	21	29
	Themed	17	25
Crime Admin	Candidate	26	40
	Themed	9	21

Table 15 Theming of Sources of Waste and Actions from all four systems

5.3.4 Stage C

The purpose of Stage C was to evaluate the themed actions from Stage B in a focus group identifying the highest impact actions that can be implemented according to ALARP. To achieve this the AEG used in *Call Handling* was replicated with the criteria used in the AEG adapted to the local context. The system owner for each system-in-focus was interviewed to determine a set of qualitative criteria to evaluate actions against. Each criterion was then divided into a set of exhaustive and mutually exclusive categories. The Force Crime Registrar as the system owner for *Crime Desk* and *Crime Admin* decided the priorities for the two systems were identical so the same criteria were used in each AEG. The criteria and categories agreed for use in *Switchboard* and *Crime Desk/Crime* Admin are shown below [Table 16 and Table 17]. The criteria are shown in the top row of each table and the categories for each criterion shown below in bullet points with the most desirable category at the top and least at the bottom.

The effect of an action on the Public	The effect of an action on the organisation	The effect of an action on the staff
• The action will make the process less complicated for the public • The action will make no change to how complicated a process is for the public • The action will make the process more complicated for the public	• The action will reduce the overall time it takes for the organisation to manage an enquiry • The action will have no effect on the overall time it takes for the organisation to manage an enquiry • The action will increase the overall time it takes for the organisation to manage an enquiry	• The action is achievable now given current staffing levels and training • The action is achievable in the short term given staffing levels and training (less than 3 months) • The action is achievable in the medium term given staffing levels and training (3 – 6 months) • The action is achievable in the long term given staffing levels and training (over 6 months)

Table 16 Criteria and categories from AEG in Switchboard

Cost	Benefit to the public	Benefit to UK police force	Time to implement
• Little or no cost required to implement • Some cost and resources required to implement • High cost and resources required to implement	• Increased benefit to the public • Neutral benefit to the public • Reduced benefit to the public	• Increased benefit to UK Police Force • Neutral benefit to UK Police Force • Reduced benefit to UK Police Force	• Less than 3 months • 3-6 months • Beyond 6 months

Table 17 Criteria and categories from AEG in Crime Desk and Crime Admin

In *Crime Desk/Crime Admin* the system-in-focus owner was keen to expand the number of criteria used to evaluate each action from three to four. The AEG as a tool was suitably flexible to accommodate this change however the practically and usability of the tool would be compromised due to increased complexity. The additional criteria added an additional consideration during the focus group for each action thus lengthening the total time taken to complete the AEG. A fourth criterion would also make the AEG look more complicated by increasing the number of rows by a factor of three. However when considering this change in light of Keeney & Raiffa's (1993) requirements for evaluation criteria the AEG needed to be able to demonstrate completeness. This requires that all attributes which are of concern to the decision maker are included and as in this case the decision maker was sure that all four criteria were needed the adaptations were made to include all four criteria in the AEG. The Stage C focus groups for *Crime Desk* and *Crime Admin* each included three participants. These were the Force Crime Registrar, the member of staff from Stage A and a participant from the Stage B interviews. The combined knowledge of these three staff spanned both the operational issues (by the member of staff) and the strategic issues (from the Force Crime Registrar) therefore were able to evaluate the various actions effectively. The focus group for *Switchboard* consisted of the Supervisor with responsibility for *Switchboard* (from Stage A), the Customer Contact Manager, the Quality Assurance Officer and two members of *Switchboard*. These five participants were chosen for their combined knowledge of *Switchboard*, they also represented the stakeholders which buy-in would need to be secured from for the changes to be implemented. Principally management and staff from *Switchboard*. Like with Stage C for *Call Handling* the application and use of the AEG was broadly unproblematic in all three applications. Participants were able to identify the appropriate placing of each action for each criterion. Any divergence of opinions were discussed until there was consensus among the group.

The final contextual element to be agreed in Stage C was which combinations of criteria rankings would identify high, medium and low priority actions in the AEG. For example in *Crime Desk* and *Crime Admin* the Force Crime Registrar had a clear time frame they did not want to go beyond. Therefore any actions judged to take longer than 6 months regardless of other ratings were given a low priority. As with *Call Handling* this took place over a week after the AEG focus group so the participant couldn't remember which actions had been placed in which row of the grid.

5.3.5 Stage D

The aim of Stage D was to agree the programme deliverables to be implemented by taking into consideration wider work plans and system goals. The further studies replicated the same process in Stage D as used *in Call Handling*. The ratings of actions from each Stage C were considered alongside wider organisational goals. In all instances the Stage D participants were the same as those from Stage A with the Quality Assurance Officer and Customer Contact Manager also present for *Switchboard*.

5.4 Limitations of individual system modelling

In the further study WASAN was applied to *Switchboard, Crime Desk* and *Crime Admin*. During each application the same methodological conventions were replicated from *Call Handling*. The output from the analysis of each system was a set of program deliverables aimed at reducing time wastes in the operation of each system. Each deliverable was evaluated for its potential impact at the individual system level. They were also evaluated at the higher order system level in Stage D to check they were sensible given the higher order goals of the system. Despite including a higher authority sign-off in Stage D there was concern the individual sets of program deliverables did not fully represent the issues of waste management apparent in the wider meta-system. Two shortcomings in the single system level analysis have been identified. First, apart from some consideration in Stage D the programme deliverables did not analyse the impact on other systems beyond the system-in-focus. That is, the actions from the analysis of *Switchboard* did not necessarily benefit others systems. Second, during the analysis of the individual systems a range of sources which affected more than one system were identified.

Analysis of the individual system models did not sufficiently represent the systemic nature of the behaviour of waste across the expanded system. Therefore to understand the behaviour of waste across the expanded meta-system a second level analysis was conducted that looked at the horizontal dependency across all four models. The next section reports this analysis within the UK Police Force to understand how modelling an expanded system in WASAN can identify horizontal dependency of systems. This will focus on identifying if this approach leads to a greater understanding of the impact of waste across the meta-system.

5.5 Identifying the gap - Theoretical contribution of WASAN

The first stage of the further study identified that individual level analysis of WASAN models did not adequately represent the complexity present in the real world. Sources of waste identified in an individual model did not always only affect a single system, some of the sources affected multiple systems. This was identified in the individual level analysis when one system model would reference another modelled system as the apparent source of waste, however evaluation of the referenced system identified that the source of waste was from further upstream than the identified system. Therefore analysis as the single system level didn't adequately represent the situation. For example misrouted calls from *Switchboard* were identified in the three other modelled systems. This shows that members of the public were routed to the incorrect system from the *Switchboard*.

Each of the three models offered a different perspective of the waste and how to manage it. Therefore solely relying on analysis of a single system would not truly represent the situation. Analysis of this systemic problem needs to take place at the meta-system level to identify; first, the emergent properties of the meta-system, which can only be identified when the system is considered in its entirety; and second, the root sources of waste so they can be managed once rather than each individual system managing the waste in isolation in an uncoordinated manner.

The lack of a way to identify horizontal interdependency across a meta-system is a gap in knowledge in model building. No theory or methodology exists for analysis into the meta-system as previous applications are only conducted within a single system. To understand the meta-systemic issues identified in WASAN from individual systems the scope of analysis should be expanded to consider the impact of waste system-wide.

This chapter addresses this gap in PSM theory and practice by showing this problem was addressed in WASAN through the further study. The further study identifies three criteria required for system models to properly identify the horizontal dependency across an expanded system. This approach to model building is a novel approach and is considered in relation to the broader theory and the methodology of PSMs in the Discussion Chapter.

5.5 Modelling the expanded system in the UK Police Force

To understand how to model the expanded system to identify the impact of waste across the meta-system an additional layer of analysis was conducted across all four system models. This phase of analysis took place after the analysis of all individual level models had been completed and reported to the system owners. As it was beyond the original scope of the project additional consent was sought from the system owners to re-analyse the data in this new way. The additional analysis was conducted with full consent from the UK Police Force.

There were two aims of the second analysis (SA) these were:

SA1. To understand how can individual level models be combined to show the interrelationships present in an expanded system.

SA2. To understand if following the doctrine of expansionism lead to additional learning beyond that of the individual single systems.

The practical mechanics of modelling the expanded system are explored below with an example of a modelled system. Based on this and the experience in the further study three criteria that are required to model an expanded system are identified and SA1 is answered.

To model the expanded system the original data and models were revisited to identify cross cutting wastes that affected more than one system within expanded system. The original theming process was revisited to identify instances where an upstream source of waste was identified as being generated by another modelled system. The audit trail for the original applications detailed all wastes and how they were themed. Each of the four audit trails was revisited to identify upstream sources of waste that could be attributed to other modelled systems. In the few instances where there was ambiguity attributing a source of waste to a modelled system the original record from the Stage B interview was consulted where a fuller description of the waste was recorded. If this wasn't sufficient then the original recording of the interview was used to derive the correct meaning. Comments from interviewees on the interactions between the four modelled Level 1 systems were coded to identify the upstream black box shown in Figure 33. When instances of cross referencing were identified (that is the upstream black box could be identified as one of the other modelled systems) data pertaining to the identified system was analysed to identify information that could help with understanding with the management of the originally identified waste in the system in focus. This could relate to why the waste is created, or if the waste is actually generated further upstream.

For example the *Crime Admin model* identified misrouted calls as source of waste. The recording from the individual interview where the waste was identified was revisited to validate the meaning of the waste and to identify comments from the interviewee that could be useful to understanding the impact of the waste on other systems. During the *Crime Admin* interview the interviewee said "*We get mixed up with Crime Desk*", this referred to calls that should have gone to *Crime Desk* being misrouted to *Crime Admin* from *Switchboard*. As the *Switchboard system* had been identified as a black box we could model the impact of that waste on the *Crime Desk system* in Figure 33. It was now possible to expand the search for information related to the misrouting of calls from *Switchboard* to the data gathered in the Switchboard Study. In this instance data from the *Switchboard* interviews pertaining to misrouted calls from *Switchboard* was identified as shown in Figure 34.

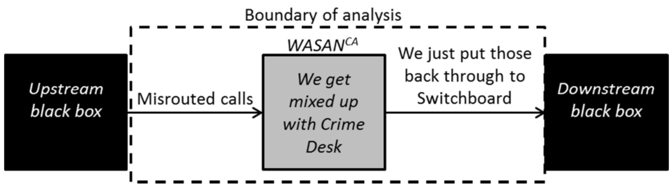

Figure 33 WASAN model of Crime Desk

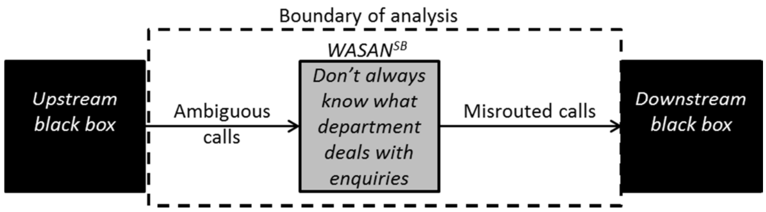

Figure 34 WASAN model of Switchboard

As these two models reference each other through the replicated Channel of misrouted calls they could be aggregated to give an expanded system model as shown in Figure 35. The old boundary of analysis from the individual models only covered the system-in-focus and the Channels In and Channels Out, the boundary of analysis for the expanded model covers both systems, the linking channel and the Channel In to the first system and Channel Out of the second system. This expanded boundary allows for a greater appreciation of the interactions across the meta-system.

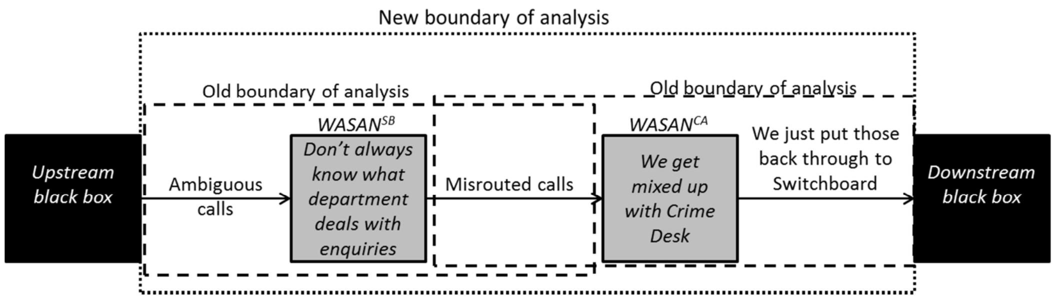

Figure 35 Expanded system model of Switchboard and Crime Desk

The analysis of the expanded system modelled each instance where a waste or action impacted on any other unit to generate expanded system models to be considered by decision makers at the UK Police Force. During this analysis the researcher was keen to understand what the minimum requirements for systems to be combined to model an expanded system. Three criteria were identified which will be considered in more detail in the following section. These criteria are: replication of approach and context; referencing across models; and, aggregation of models.

5.6 Requirements to model the expanded system

The above section identified that three criteria are required in individual models for them to be successfully combined to build models of the expanded system. These were: replication of approach and context; referencing across models; and, aggregation of models. This section examines these criteria in greater detail to answer the first aim of the second analysis in the further study "*how can individual level models be combined to show the interrelationships present in an expanded system*".

5.6.1 Replication in WASAN

The first criteria identified during the further study as required to model the expanded system was replication of analytical conventions across all models. Chapter 4 of this thesis identified that for a methodology to be generically applicable (so it can be replicated in different systems) it must have two classes of elements. First, those which require methodological replication in all applications and, second, those which are adapted depending on the context. For models to be combined across the expanded system they must adhere to the same methodological modelling conventions. That is, the same methodological approach must be used to build each model, in the further study these were the elements identified in Figure 35. The methodological replication ensures each model has the same structures and so is compatible. However, when modelling the expanded system methodological replication alone was not sufficient alone to explain the consistent replication required across models of the expanded system. Some contextual elements must also be replicated across models in the expanded system. The replication of these elements ensures consistency across models in the expanded system so that when the models are combined they are commensurate with one another. For example, combining models that consider different wastes would not lead to any meaningful analysis e.g. a model concerned with reducing wasted time and a model concerned with reducing transfer of nuclear contaminant are incommensurate with each other and cannot be combined. Therefore this section introduces an additional class of elements alongside methodological replication and contextual elements when considering modelling an expanded system. These are contextual elements that require replication within expanded systems and so are called contextual replication.

To understand the extent to which replication of contextual elements was required within the Call Handling study this section draws from Table 9 which shows the methodological and contextual elements of WASAN. The key contextual elements from Table 9 which required replication across the expanded system in the further study are discussed below explaining why they had to be replicated across the system models of the expanded system.

For WASAN the elements requiring contextual replication are all found during Stage A, reflecting upon this the author identified that it is in this stage the scope and boundary of the system (and intervention) is defined. It is therefore these elements which define the boundary of the intervention which must be consistent across the different models so that the analysis can transcend multiple models in the expanded system. The elements requiring contextual replication across models were: the waste to be reduced; and, the Channels In and Out of the system. For waste the expanded model was only useful if it could trace the effects of the same waste across different systems. Here waste is considered in two levels, first, we consider the overall aim of the analysis, in this case the aim was to reduce wasted time within the systems. For the combination of models to be successful all modelled systems must aim to reduce the same waste (which in further study was wasted time). However for successful combination of models in the expanded system we must not only consider the overall waste to be reduced but how this waste has been identified in each modelled system. Figure 35 shows the combination of two models from the further study, these models were combined as they both showed the same specific waste from different perspectives, $WASAN^{SB}$ showed the impact of ambiguous calls while $WASAN^{CA}$ showed the impact these calls have when they are misrouted. Only when the same specific waste is transferred through the expanded system is there a need to model the expanded system. Therefore both the general waste and the specific waste must be replicated in combined models.

With respect to Channels In and Channels Out there must be replication of these channels between combined models. The source of waste must exit out of one system into a new system through the same channel. In Figure 35 the middle arrow labelled *Misrouted calls* identifies the Channel Out of *Switchboard* and Channel In to *Crime Admin*. These channels must be replicated so the waste can move through the meta-system, if they are not then there will be no link between systems by which the source of waste can travel.

In addition to the above elements that required contextual replication the further study also replicated other contextual elements, these were replicated as they had been tested during the application in *Call Handling* and so known to work in the context. However it may have been possible to combine the models without replication of these elements as they did not frame the system. These elements were: the mode of operationalising WASAN, the Keywords used in the external analysis of operations and the keywords used in the internal analysis of operations.

5.6.2 Self-referencing in WASAN

WASAN models use the concept of a black box to limit the boundary of analysis. Figure 36 shows the $WASAN^{CA}$ with 'misrouted calls' as a waste source emanating from an upstream black box. The waste source exits the black box when misrouted calls enter *Crime Admin* from the black box through the Channel In, the misrouted calls cause waste within the *Crime Admin system*. If the waste is not absorbed by *Crime Admin* then it could be passed further downstream through a Channel Out of *Crime Desk*. This would is represented as a second black box downstream from $WASAN^{CA}$. The WASAN boundary of analysis, shown as a dotted line, focusses on the channels (represented as arrows) and the *Crime Admin System* (represented as the grey box).

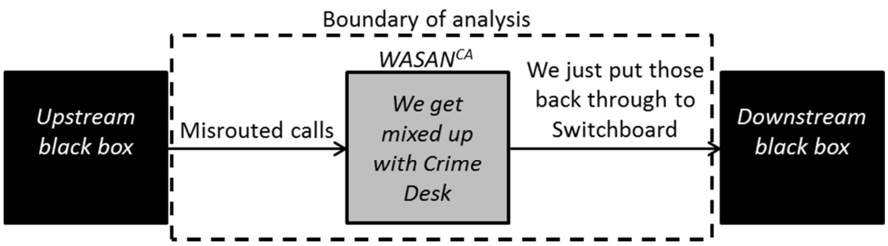

Figure 36 Upstream system as a black box

When modelling the expanded system the boundary of analysis is expanded beyond a single system. This is done by modelling the black boxes. For the models to be commensurate the same modelling conventions and context outlined in

Section 5.6.1 must be adhered to. Self-referencing in the models provide a route map to move from one model to another.

In the further study, during Stage B of *WASAN*^{CA} a participant identified *Switchboard* as the source of misrouted calls: "We get mixed up with Crime Desk sometimes … we can just put those back through to Switchboard". Thus, we can move from *WASAN*^{CA} to model the upstream black box at *System*^{SB}*.* Modelling the upstream system may help us to understand how and why the *Switchboard* misroutes calls to *Crime Desk*. Modelling upstream systems moves the analysis beyond understanding a single system and provides a meta-system to understanding of the problem. Referencing other systems was endemic in the interviews as participants from all four systems identified other units which caused waste within their unit. Table 18 presents instances where a model/interviewee referenced an up/downstream system. The x axis shows from which model the issue was raised, with the y axis showing which system is being discussed. Thus, the first row presents views on *Switchboard* from interviewees from *Call Handling*, *Crime Desk* and the *Crime Admin*. A description and context of the waste is provided [underlined] along with a quote [in italics] from the participant. Table 18 shows that misrouted calls are a systemic problem affecting all systems within *Customer Contact.*

A single model [Figure 36] does not convey the breadth of system-wide issues that must be addressed to eliminate misrouted calls within *Customer Contact.* This is only evident from a meta-systemic analysis of the situation using the data in Table 18. With this data it is possible to aggregate the WASAN models to show the horizontal dependency of systems across the expanded system.

5.6.3 Aggregation of models in WASAN

Aggregation combines models that were built using the same modelling conventions where one model references another modelled system. In the further study two types of aggregated models were identified: (1) waste chains, where an action from an up/downstream black box caused a waste which could be explored by modelling the black box; (2) waste transference, where a policy decision from a Level 0 system transferred waste from one Level 1 system to a different Level 1 system.

To illustrate how modelling aggregated waste chains shows the expanded system and provides more insight into the problem situation than viewing each waste chain in isolation, misrouted calls from *Switchboard* [Figure 36] is expanded into a waste chain. Figure 37 expands $WASAN^{CA}$ to include the upstream $WASAN^{SB}$ as the source of misrouted calls and includes other systems which *Switchboard* misroutes calls to. Also, the impact of waste is traced downstream from $WASAN^{CA}$ either as calls are sent back to *Switchboard* or as Call Handlers are unavailable to answer incoming calls. This illustrates the importance of identifying how a problem affects a meta-system as addressing this problem in $WASAN^{CA}$ would not fix the wider problem. Seeing this broader perspective by modelling the upstream and downstream black boxes (with different interviewees) to show the expanded system helps to identify route causes (in this case ambiguous calls) and so allows more effective system solutions to be considered than if the systems had been considered in isolation.

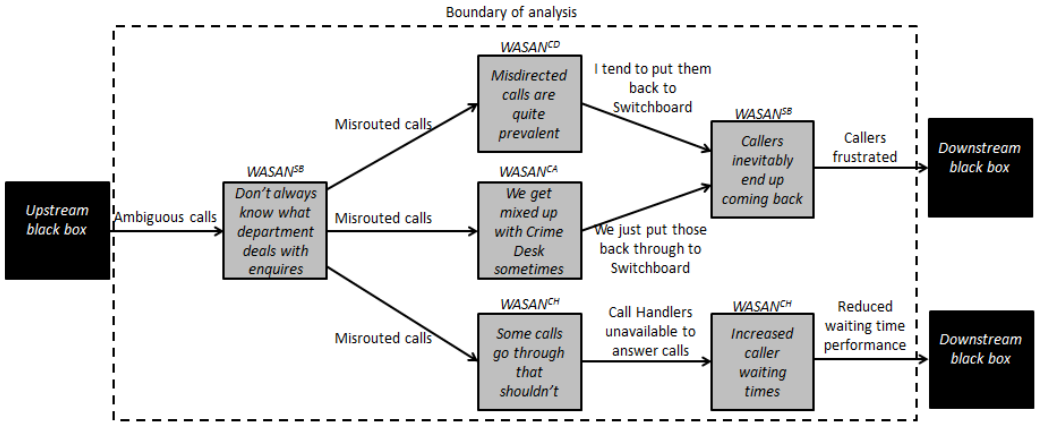

Figure 37 Misrouted calls waste chain (for illustration)

System Referenced	Where the issue was raised			
	$WASAN^{SB}$	$WASAN^{CH}$	$WASAN^{CD}$	$WASAN^{CA}$
$System^{SB}$		Calls put through *to Call Handling* by *Switchboard* that shouldn't and result in other calls not being answered "Some calls go through that shouldn't go through … really it should have gone to another department … but while we are dealing with that, calls that are aimed more for us are not being answered."	Misrouted calls from *Switchboard* that get redirected back to *Switchboard* "Misdirected calls are quite prevalent … I think Crime Desk is the easy option as we have to answer the phone … I tend to put them back to Switchboard and tell them they need to go too [pause]."	*Crime Admin's* responsibilities mixed up with *Crime Desk's* "We get mixed up with Crime Desk sometimes … we can just put those back through to Switchboard … we can [route them directly to Crime Desk] but its more to highlight to Switchboard that we are not Crime Desk."
$System^{CH}$	Calls bounced back to *Switchboard* from *Call Handling* "There is some waste when callers inevitably end up coming back to the Switchboard because they have been put through to the wrong place and they don't always know where to put them through too."		*Call Handlers* taking details of historic crime for *Crime Desk* to follow up Comms Centre [Call Handlers] sit and reproduce all that in a STORM incident … they will then switch it through to the Crime Desk it's up to the Crime Desk then to chase the victim to manage the crime report."	$WASAN^{CA}$ did not reference $System^{CD}$
$System^{CD}$	Calls bounced back to *Switchboard* from *Crime Desk* "Switchboard don't always know what department deals with particular types of enquiries."	*Call Handlers* tied up issuing crime numbers I've got calls for service for fights and things that are going on but I've got Call Handlers tied up with doing Crime Desk's job.		Crime reports from Crime Desk with missing information "We waste a lot of time with stuff coming through to us that hasn't been completed properly, the C1's [crime reports]"
$System^{CA}$	Calls bounced back to *Switchboard* from *Crime Admin* "Switchboard don't always know what department deals with particular types of enquiries."	$WASAN^{CH}$ did not reference $System^{CA}$	$WASAN^{CD}$ did not reference $System^{CA}$	

Table 18 Quotes referencing other systems

The second example of aggregation in WASAN is waste transference, this occurs when a change in policy transfers waste between two systems in the expanded system. Here, a decision is made that benefits a single Level 1 system by reducing the waste in that system, but transfers the waste to another Level 1 system. If there is a failure to understand the decision in relation to the meta-system the decision could be accepted and implemented without understanding potential unintended consequences which could be detrimental to the overall system. Modelling the expanded system helps avoid this. To illustrate using Figure 38, in the further study the *WASAN*^{CD} model identified '*Sending callers to Action Fraud'* as a waste. Action Fraud is a National Centre that investigates some types of fraud. In *WASAN*^{CD} an action was included for the '*Switchboard system to send these types of callers directly to Action Fraud',* the effect of this would be to bypass *Crime Desk* and avoid the waste entering the *Crime Desk system*. While this would reduce the number of callers to *Crime Desk* (a realised benefit) it would increase processing time at *Switchboard* and may require staff training (unrealised impact). If implemented by *Crime Desk*, this policy would shift the impact of the waste between the two Level 1 systems (so, in Figure 38, a source of waste enters *WASAN*^{CD} from a black box and it would be transferred to *WASAN*^{SB}). Moving the arrow from the black box away from *Crime Desk* to *Switchboard* might benefit *Crime Desk* but not necessarily the overall system. By identifying the decisions systemic effect, decision makers can balance the relative benefits and drawbacks from any decision for the entire meta-system not just a single Level 1 system. We use the expanded system model here as the decision makers at Level 0 need to make consistent comparisons between units and so the models must adhere to the same conventions.

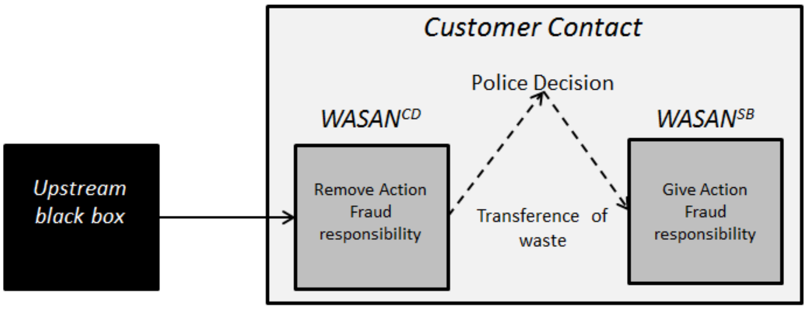

Figure 38 Change in policy results in a movement of waste between Level 1 systems

5.7 Findings Summary

The further study at the UK Police Force identified a new novel approach to model building. Current model building approaches have to take the view that either, the system boundary is closed and therefore no external influences can be considered within the analysis of a system. Or the approach has to rely on the notion of a black box (or similar) where the workings of external systems (or influences) are not understood but used as inputs without modelling why they are so. The reasons for these external influences cannot therefore be included within the analysis of the system. The only way to expand the boundary of analysis is to build a bigger model which invariably either increases in complexity or loses detail when compared to the original model. The new approach in the further study gives model builders a tool to expand the boundary of analysis to the expanded system without compromising complexity or losing detail. This new modelling technique builds multiple models of horizontally linked systems and identifies the horizontal dependency across the network of systems. Without this additional analysis decision makers within an individual system could agree and implement changes that are to the detriment of the overall meta-system, or have each individual Level 1 System owner address the same problem in their own way leading to an uncoordinated solution that doesn’t tackle the root cause of an issue. The further study identified a new solution to this problem, multiple Level 1 models are built each representing a single system. The models are then combined to show the expanded system which identifies the systemic nature of the problem without reducing the detail of the models or overcomplicating the issues that had already been identified by the Level 1 System analysis.

Considering what was the minimum requirements for the successful combination of models in an expanded system identified the three criteria. These criteria can be used to answer SA1 which was "*To understand how can individual level models be combined to show the interrelationships present in an expanded system"*. Individual level models can be successfully combined if they; first, replicate both the methodology and contextual elements requiring replication; second, reference another modelled system as a black box and source of waste; and, third, be aggregated to give additional information and insight to decision makers. This process identified two uses for this type of analysis in the further study, both showed how modelling the expanded system could uncover meta-systemic issues without compromising the individual model level understanding of the system or integrity of the individual models.

5.8 Discussion points

This chapter has considered how to use the doctrine of expansionism identified by Ackoff (1979) in WASAN at the UK Police Force to understand how to model an expanded system and what benefits there are to this for decision makers. The findings from this so far have been narrow and focussed specifically on the case context and WASAN. However the contribution to theory and methodology as a result of these findings are much broader than the UK Police Force or WASAN. To show the depth and breadth of these findings this section identifies three discussion points to be considered in Chapter 6 where learning specific to this research project is expanded into a wider context. These three points are briefly identified below.

During the analysis of the further study the researcher identified potential parallels between the horizontal modelling of the expanded system and the vertical modelling of recursive systems from VSM (Beer, 1981), both are a tool for conceptualising the interrelationships between systems in a meta-system. These parallels are considered in the discussion. *Discussion Point 6 considers if modelling a horizontally expanded system constitutes a new type of recursion.*

In the further study the modelling the expanded system in WASAN provided insights into the interrelationships of different modelled systems. The findings were able to show that in this specific instance modelling the expanded system is a useful tool for understanding more about the behaviour of waste across multiple systems. However the generic benefits of modelling the expanded system were not shown. Understanding these generic benefits will answer SA2 and "*understand if following the doctrine of expansionism lead to additional learning beyond that of the individual single systems*". *Discussion Point 7 considers the generic benefits of modelling the expanded system.*

The aim in answering RQ4 is to show WASAN can make contributions to the theory and methodology of PSMs. According to Rosenhead & Mingers (2001) PSMs constitute a 'New Paradigm of Analysis' with a common philosophy. Therefore generic findings applicable to WASAN should also translate to other PSMs. *Discussion Point 8 considers if modelling the expanded system is applicable to PSMs beyond WASAN.*

5.9 Summary of Findings 2

This chapter has presented the findings relating to RQ4 ""*Can philosophical, theoretical and methodological contributions identified in one PSM be shown as relevant in others, thus showing a common framework?*". To achieve this the chapter has explored how the doctrine of expansionism (Ackoff, 1979) can be used to identify the relationship between models of systems on the same hierarchical plane. This novel application was identified as a contribution made by WASAN to qualitative modelling theory and methodology. Therefore to answer RQ4 *Discussion Point 11 considers if modelling the expanded system can be shown to be relevant to PSMs*. If this can be shown then it will provide the final element of proof to confirm WASAN as a generic problem structuring method.

Chapter 6

Discussion

6.0 Introduction to Discussion

The aim of this thesis has been to provide an in depth understanding of PSMs by a critical analysis of the philosophical, theoretical, and methodological position of PSMs. To achieve this, the fringe PSM WASAN was deployed in an action research framework in a UK Police Force. This resulted in a cycle of formulating a plan, taking action to meet the plan, and reformulating the plan based on fact finding (Cunningham, 1976)—where learning related to the UK Police Force, the methodology WASAN, and the framework of ideas underpinning WASAN (Checkland & Holwell, 1998) was identified. That is, by employing action research, this thesis is able to provide knowledge of the underpinning assumptions relating to the philosophy, theory, and methodology of the approach used. To focus the analysis of these issues, four research questions were identified during the Introduction. This discussion answers the following four research questions:

RQ1. What are the defining philosophical, theoretical, and methodological features of PSMs?

RQ2. How can PSMs be developed into suitably generic approaches applicable in multiple problem contexts?

RQ3. How can the four pillar framework be operationalised to identify the defining features of PSMs in new approaches?

RQ4. Can philosophical, theoretical, and methodological contributions identified in one PSM be shown as relevant in others, thus showing a common framework?

A key aspect of this thesis has primarily been concerned with the development of the theory and methodology of WASAN. This aspect of the research design was necessary to limit the primary data collection and analysis to a single context in which the Research Questions could be explored and understood. These findings inform the central aim of this thesis and will be considered in relation to each of the Research Questions. Hence, this Discussion will broaden the interpretation of these findings beyond WASAN by considering their implications for the theory and methodology of PSMs in general. To aid this process, eight Discussion Points [Table 19] were identified in the thesis which ground the findings in the current literature and show how this research furthers knowledge. By exploring the context of the research through these Discussion Points this chapter identifies the contributions to knowledge from this thesis. Finally, the chapter will consider the central aim of the thesis, bringing together the learning from all four Research Questions to critically analysis the philosophy, theory, and methodology of PSMs.

Research Question	**Discussion Point number**	**Discussion Point**
Research Question 1	1	If Rosenhead and Mingers were correct in asserting PSMs have different underpinning assumptions when compared with other approaches.
	2	If the concept of knowledge leaks is useful for practitioners and researchers to consider when designing an intervention.
Research Question 2	3	If smart bits can be used by developers of OR approaches to combine methods without mixing philosophies.
	4	If for an approach to be generic it must have methodological elements which are replicated regardless of context and contextual elements which adapt the methodology to the context.
Research Question 3	5	If the four pillar framework can be applied to other fringe PSMs to strengthen their case for inclusion alongside the existing set of PSMs.
Research Question 4	6	If modelling a horizontally expanded system constitutes a new type of recursion.
	7	The generic benefits of modelling the expanded system.
	8	If modelling the expanded system is applicable to PSMs beyond WASAN.

Table 19 Discussion points

6.1 Research Question 1: What are the defining philosophical, theoretical, and methodological features of PSMs?

The findings from this research project identify 15 features of PSMs that are central to their identity; these features can be used to constitute a new novel definition for PSMs. This definition is novel because it is grounded in both the philosophical assumptions relating to paradigm (ontology, epistemology, axiology, and methodology) and a broad literature base from 40 years of PSM research, development, and use. The definition is encompassed in the four pillar framework which identifies 15 questions that can be asked of an approach to identify if it is a PSM or not. During the development of the framework, the researcher identified a new concept of knowledge leaks; this relates to how when building models in PSMs facilitators need to be cautions that the research design does not allow modelled knowledge to be lost (leaked) between phases of analysis. This concept is a new and novel contribution to the methodology of PSMs as it should aid in the design and delivery of research projects. The identification of the four pillar framework and definition found three further important contributions beyond the remit of answering RQ1. First, the framework can help with the development and classification of PSMs. This is a novel contribution to the philosophy, theory, and methodology of PSMs. Second, identifying an underpinning framework across PSMs opens up new research avenues; currently, the majority of research into PSMs is focussed on the development of theoretical contributions in relation to a specific PSM. This project identifies that research can now be focused on developing certain aspects of PSMs (as identified in the four pillar framework). Contributions to the framework would have the added benefit of being applicable across PSMs, rather than only a single PSM. Third, the four pillar framework identifies an important question about what is it that makes an approach a PSM; the four pillar framework works as a definition for PSMs by identifying if an approach demonstrates particular features. These features are the manifestation of the philosophical assumptions that underpin PSMs. Therefore, it is the features (and underpinning assumptions) which should determine whether an approach is a PSM or not, rather than historic naming conventions. This emphasis is important as it says that if SSM was used without the epistemological assumptions which advocate facilitation, stakeholder learning, or political feasibility, it would not be a PSM (Hall, 1962). This change in emphasis about what should (and should not) be considered a PSM is a novel contribution to theory.

This section now considers these findings in more detail, showing the novelty of the contributions and placing the findings next to the existing literature to show where there is overlap and where the findings add something new to the existing body of research.

To show the novelty of the four pillar framework, this section briefly presents the core underpinning argument regarding the philosophy, theory, and methodology of PSMs. In doing so, the discussion shows how PSMs and their underpinning assumptions have been defined thus far may have stifled innovation in the field and how this has been addressed here. The seminal work on PSMs by Rosenhead (1989) in 'Rational Analysis for a Problematic World' identified that PSMs constituted a new paradigm of analysis when compared with traditional OR. The book was not contested in terms of the paradigm shift and established the benchmark for future research into PSMs. As was identified earlier in this thesis, the only consistent naming convention for PSMs emanated from that text where approaches included within it were considered PSMs, thereby by establishing a form of exclusivity. The exclusivity of PSM definition inadvertently stifled the space for a rigorous debate concerning the philosophical, theoretical, and methodological features of PSMs, with other approaches having to argue their own (often unsuccessful) justification for inclusion as a PSM. This early work that set aside

PSMs as distinct from other approaches was based on unsubstantiated claims; this framed the architecture for defining PSMs, which still holds true today.

Rosenhead & Mingers (2001a) argued that the methods well suited to quantitative OR for use on tame problems follow an objectivist stance “that sees problems essentially as independent of individuals participants’ views and beliefs” (2001a p.6), and parallels the natural sciences with the focus on positivism. Problem solving approaches suited for wicked problems required “a subjectivist stance that recognizes the importance of participants’ perceptions in defining or even constituting a ‘problem’ in the first place” (2001a, p.6) the shift to the interpretivist paradigm for PSMs was consolidated.

To achieve this, Rosenhead & Mingers (2001a) made the narrow assumption that because the wicked and tame problems are diametrically opposed and each require their own underpinning assumptions, the assumptions underpinning the two paradigms should also be diametrically opposed. Therefore, they took the assumptions underpinning the traditional paradigm and defined the opposing state as the assumptions underpinning the new alternative paradigm. While these assumptions are supposed to represent the interpretivist paradigm, their means of development suggest they are perhaps anti-objectivist. Table 20 presents the opposing set of philosophical assumptions identified by (Rosenhead & Mingers, 2001a).

It was accepted at the time that when these characteristics of the qualitative paradigm for OR were developed in the 1970s, that they were rather theoretical and were at best a blueprint for future approaches that may be developed (Rosenhead & Mingers, 2001a); however, they have remained perhaps the most dominant set of stated assumptions underpinning PSMs. While the assumptions relating to the alternative paradigm are internally coherent, it is accepted that over the 40 years since these characteristics were first postulated, the approaches established as PSMs do not all demonstrate all of the identified characteristics (Rosenhead & Mingers, 2001a). Therefore, while this set of assumptions could have been considered a good starting point in the 1970s, it is time to revisit the philosophical, theoretical, and methodological position of PSMs.

Characteristics of the Quantitative OR paradigm	Characteristics of the Qualitative OR paradigm
Problem formulation in terms of a single objective and optimization. Multiple objectives, if recognized, are subjected to trade-off onto a common scale.	Non-optimizing; seeking alternative solutions which are acceptable on a separate dimensions, without trade-offs.
Overwhelming data demands, with consequent problems of distortion, data availability and data credibility.	Reduced data demands, achieved by greater integration of hard and soft data with social judgements.
Scientization and depoliticization, assumed consensus.	Simplicity and transparency, aimed at clarifying the terms of conflict.
People are treated as passive objects.	Conceptualizes people as active subjects.
Assumption of a single decision maker with abstract objective from which concrete actions can be deduced for implementation through a hierarchical chain of command.	Facilitates planning from the bottom-up.
Attempts to abolish future uncertainty, and pre-take future decisions.	Accepts uncertainty, and aims to keep options open.

Table 20 Comparison of the paradigms of analysis in OR (from Rosenhead & Mingers, 2001a)

This research project adopted a different approach in defining PSMs, as identified above. The development of the four pillar framework was grounded in the philosophy, theory, and methodology of PSMs. At the core of the framework are questions relating to the ontological, epistemological, axiological, and methodological assumptions of an approach. This design decision gave the approach depth in rooting each question to the underlying assumptions of an approach and also gave the framework breadth. The answer to any single question in isolation will not represent the totality of PSM features, but all 15 features combined go some way in identifying the underlying features and assumptions of PSMs. Each of the four pillars was understood in relation to PSMs based upon how they were operationalised and interpreted by Mingers (2003). Focusing on these intrinsic elements of form and application of any technique, the four pillar framework [Figure 39] offers a novel classification by which to assess and explain the features of PSMs. A thorough review of the literature was conducted to identify the individual questions sitting within each of the high-level constructs. This ensured that unlike the characteristics in Table 20, the features identified in the four pillar framework are rooted in both philosophy and practice; thus, it is a novel contribution to the philosophy, theory, and methodology of PSMs.

Pillar 1: System characteristics
Q1 Does the approach draw an open boundary around the system? Q2 Does the approach understand there are systems as different hierarchical levels? Q3 Does the approach build a qualitative model? Q4 Does the modelling approach try to manage complexity? Q5 Does the approach model an identifiable system?
Pillar 2: Knowledge and involvement of stakeholders
Q6 Does the approach build a model in a facilitated way? Q7 Does the approach focus on participants learning about the problem? Q8 Does the approach aim to produce politically feasible solutions over optimal solutions?
Pillar 3: The values of model building
Q9 Does the model reflect the different social realities of the participants? Q10 Is the model building process generic so it can be transferred to multiple problem contexts? Q11 Does the approach rely on showing procedural rationality to show reliability in outcomes? Q12 Does the model build a validated audit trail of the decision making process?
Pillar 4: Structured analysis
Q13 Does the approach structure knowledge through different stages of analyses? Q14 Are there distinct phases for divergent and convergent thinking? Q15 Does the approach manage knowledge through the methodology to avoid 'Knowledge Leaks'?

Figure 39 The four pillar framework

The literature review identified 14 of the 15 features of PSMs that are included within the framework. The 15th was developed by the researcher while reviewing the framework for completeness. These 15 questions have been used to form a written definition for PSMs. The corresponding question number for each point is shown after each point in brackets.

The findings from this project show that PSMs manage the complexity present within a system (Q3), building models of systems that are able to retain the complexity of the situation as opposed to techniques that reduce and discard complexity. The systems model recognises interaction between the system-in-focus and other surrounding systems; therefore, the system boundary is open (Q1). There is also recognition of hierarchy between surrounding systems or concepts (Q2). Finally, the system being modelled is identifiable so it can be modelled consistently, perhaps using a specific modelling language or conventions (Q5). Epistemologically, PSMs build qualitative models (Q5) using facilitation (Q6) where participants are encouraged to learn about the problem through a process of involvement (Q7) in a bid to increase political feasibility of the outcomes (Q8). The axiological aims of PSMs are to build models that reflect different social realities of participants (Q9) by using generic model building techniques (Q10). The PSM should follow a rational process on which to base conclusions on (Q11) and be transparent with a clear audit trail of decision making (Q12). Finally, in terms of methodology, a PSM will have multiple stages of analysis (Q13). Included within the methodology are stages of divergent thinking where participants are encouraged to think broadly about the different potential options available and some will be convergent thinking stages where participants are encouraged to discard less favourable options and select more favourable options (Q14). Finally, as the analysis is staged the approach needs to ensure that knowledge is not lost between stages through poor methodological design or misrecording of data—the so-called knowledge leaks (Q15).

Since the development of the four pillar framework (and submission of the paper to the European Journal of Operational Research) Yearworth & White (2014) have published a non-codified definition for PSMs which they use to identify if approaches used in engineering firms constitute PSMs. This work supports this research project in showing there is a need to identify the features of PSMs to help strengthen the field.

<u>6.1.1 Discussion Point 1 considers if Rosenhead and Mingers were correct in asserting PSMs have different underpinning assumptions when compared with other approaches</u>

Discussion point 1 considers the extent to which Rosenhead and Mingers (2001a) were correct in their assertion that PSMs make different underlying assumptions to non-PSMs. This is considered by re-examining the findings from the four pillar framework and comparing and contrasting these findings with the original assumptions made by Rosenhead and Mingers (2001a) about the alternative paradigm, as outlined in Table 20.

The four pillar framework was tested by identifying if the 15 features within it were present in 8 established OR approaches. Of the 8 approaches, 3 are considered PSMs, while the other 5 are not. As shown in Section 2.4, all 15 features were identified in the 3 established PSMs, while the 5 non-PSMs all had some of the features of PSMs missing. This test was a test of the framework rather than of the 8 approaches; the features of the framework were identified from a broad search of the PSM and surrounding literature. As much of the literature used to develop the framework was related to a specific approach, the framework needed to show that all 15 features were applicable to all the established PSMs. The test showing each feature being present in each of the PSMs is evidence of commonality among the assumptions underpinning PSMs. The other supporting evidence for the accuracy of the framework was that the 5 non-PSMs were not identified as having all 15 features and therefore cannot be considered PSMs; this shows that the framework helpfully delineates PSMs from non-PSMs.

This section now considers the differences between the philosophical assumptions made by Rosenhead & Mingers (2001a) about the new paradigm of analysis and the underpinning assumptions regarding PSMs identified in the literature review, which are included within the four pillar framework. Rosenhead &

Mingers (2001a) identified 6 assumptions that they claimed underpinned the ‘New Paradigm of Analysis Table 21.

The reason Rosenhead & Mingers (2001a) defined these assumptions was to show the difference between PSMs and quantitative approaches. Therefore, for a meaningful comparison between these assumptions and the features identified in the four pillar framework, only features which differentiated PSMs and non-PSMs should be selected. This narrows the comparison from 15 features down to 10. This is acceptable as some of the features in the four pillar framework are likely to be features of all OR or even all problem solving approaches and so are still warranted in the framework.

The six characteristics of the alternative paradigm, as identified in Rosenhead & Mingers (2001a), are shown in the left-hand column of Table 21. The 10 delineating questions from the four pillar framework are shown in the corresponding row of the right-hand column, with the last row listing the features that are not covered by any of Rosenhead and Mingers’ (2001a) original assumptions.

The findings have shown that Rosenhead and Mingers (2001a) were correct in their assertion that the alternative paradigm makes different assumptions regarding problem-solving and the nature of problems than traditional OR. However, their methodology for defining this paradigm was somewhat narrow. Under their own admission, the characteristics were broadly theoretical, defined as the opposite state to that of quantitative OR. After considering the differences between the theoretical assumptions made by Rosenhead and Mingers (2001a) summarised in Table 21, it is evident that these assumptions need to be reconceptualised. The need for this is apparent due to the array of new approaches, such as Issues Mapping (Cronin, Midgley, & Jackson, 2014) and Visioning Choices (O’Brien &

Meadows, 2006). Added to this is the need to accommodate some of the features that apply to both qualitative and quantitative OR approaches; quantitative OR is part of the history of PSMs and therefore a number of features from OR are also important features of PSMs.

Characteristics from Rosenhead and Mingers Alternative Paradigm	**Characteristics of only PSMs from the Four Pillar Framework**
Non-optimizing; seeking alternative solutions which are acceptable on a separate dimensions, without trade-offs.	Q8: Political feasibly over optimality
Reduced data demands, achieved by greater integration of hard and soft data with social judgements.	Q9: Represent different social realities
Simplicity and transparency, aimed at clarifying the terms of conflict.	
Conceptualizes people as active subjects.	Q6: Facilitated model building
Facilitates planning from the bottom-up.	
Accepts uncertainty, and aims to keep options open.	Q3: Managing complexity
Not included	Q1: Open system boundary
	Q5: Qualitative model building
	Q7: Participant learning
	Q11: Procedural rationality
	Q13: Different stages of analysis
	Q14: Phases of divergent and convergent thinking

Table 21 Rosenhead and Mingers' (2001a) assumptions compared with the four pillar framework

<u>6.1.2 Discussion Point 2 considers if the concept of knowledge leaks is useful for practitioners and researchers to consider when designing an intervention</u>

As already identified, the final element (Q15, knowledge leaks) of the four pillar framework did not come from the literature. It was developed in response to a gap identified by the researcher during the development of the framework. There was a requirement in the framework for PSMs to build knowledge over a series of stages. The staged approach was necessary to fill the methodological requirements of PSMs as different techniques and different stages of both divergent and convergent thinking which need to be incorporated into a PSM. When considering the linkages between these different stages, the researcher identified that there would be a possibility for the knowledge that is captured and modelled during an intervention to be lost through misrecordings or inefficient methodology design when transitioning between different stages of analysis. That is, knowledge created during stage/cycle 1 of a methodology could potentially fail to be passed through to later stages/cycles. This would lead to wasted effort during the stage in which the knowledge was created and reduce the richness of the findings. To understand how this can be minimised, this project draws from Ruggles' (1997) three-staged knowledge management framework from an organisational context. Stage 1: Generation of knowledge—this includes knowledge creation, knowledge acquisition, synthesis of knowledge, fusion of knowledge and adaptation of knowledge. Stage 2: Knowledge codification—this includes the capture and representation of knowledge. Stage 3: Knowledge transfer—applying this to knowledge management in PSMs, knowledge is created during a stage of a PSM intervention. This is likely to be as a result of interaction between participants or between the facilitator and a participant and could take the form of a verbal statement about how the system is perceived by the participant. This knowledge then needs appropriate codification (documentation), which is most likely through some form of modelling given the PSM/soft OR roots. Finally, the model is used during latter stages of analysis within the PSM intervention. For example, in SODA, during an individual interview, a participant may identify a new concept to be added to an existing map (this is knowledge creation); the facilitator should then turn this new concept into a node and position it in the correct place within the existing model (this is knowledge codification). Finally, when the composite model is built at a later stage, the knowledge from the individual model is used within the composite model (knowledge transfer). If the interviewee identified the concept, but it was never incorporated into the model, then that knowledge would not be available during the later stages of analysis. The knowledge would have leaked out of the research process.

Knowledge leaks integrated well into the framework during the practical application of the four pillar framework to WASAN in Chapter 4. The findings from Q15 identified that WASAN was able to evidence that it had no knowledge leaks that were as a result of poor methodological design. That is, there was no data collected in one stage that was not considered at a subsequent stage of the analysis and there were adequate systems for recording knowledge. WASAN also had adequate ways to capture and codify knowledge for it to be transferred to subsequent stages of analysis. This shows application of this methodological finding, adding to the novelty of the methodological contribution.

6.1.3 Further contributions of the four pillar framework

The development of the four pillar framework has implications beyond answering RQ1; it can also help with the development and acceptance of new PSM approaches, as well as the development of the theory and methodology of PSMs and re-frame how we classify what makes an approach a PSM; these contributions are discussed below.

Understanding the features of PSMs identified in the four pillar framework will help with the acceptance and development of new PSM approaches. A lack of development of new approaches led to stagnation in the field (Westcombe *et al*. 2006); however, there has been a recent resurgence of development and identification of potential PSMs (for example, Wuli–Shili–Renli (Li & Zhu, 2014)). The definition provided by the four pillar framework can inform the classification of additional PSM approaches. That is not to say that the framework will drive the development of the approach. As with WASAN (Shaw & Blundell, 2010), the development of a methodology should be driven by the analytical requirement of problem contexts. If the philosophy of an approach is incommensurate with the PSM philosophy, then the approach should not make accommodations to include the undesired PSM elements just for a naming convention. Rather, it can be a starting point for more intellectual debate. However, the framework could be useful as a prompt to ask potential PSM developers if their approach had considered all the recognised elements for PSMs.

Finally, understanding the philosophy, theory, and methodology of PSMs will help with the development of theory and methodology across PSMs. To some extent, the siloed research that bore the individual development of the original PSMs still exists today. Ackermann (2012) identified that most established PSMs have been extensively developed within their own boundaries. However, there seems to be a lack of theory generated that spans across the theory and methodology of PSMs. While some recent research has evaluated PSMs (Midgley et al., 2013), theory development which takes learning from one PSM and tests its applicability in other PSMs is not common. This could point to a lack of shared understanding regarding what would constitute the theory and methodology of PSMs. It leads to the question of whether researchers prefer to adopt a less risky strategy by aligning their research interests with a specific approach and make contributions to the theory and methodology of that specific PSM. With an accepted framework of assumptions underpinning PSMs, researchers could pick out one or a collection of elements from the four pillar framework and work on theoretical contributions in relation to that specific area. This research would have a broader applicability by focusing on the framework and not just a single PSM. For example, Tavella & Papadopoulos (2014) are exploring the difference between expert- and novice-facilitated modelling. Facilitated modelling is shown in the four pillar framework to be a property of all PSMs; therefore, Tavella & Papadopoulos's (2014) could expand the boundary to examine all PSMs not just an individual approach.

This same principle could be true of other questions identified in the framework. For example, Q2 asks 'Does the approach acknowledge that there are systems at different hierarchical levels to the one being modelled?' a research project could consider this issue across all PSMs to identify principles about systems hierarchies that are generic to PSMs. This would both broaden the applicability of theory generated from the research to a wider set of methods and strengthen the theory and methodology of PSMs.

Criticisms of this framework could include the point that the answers to the questions may change based on how an approach is applied so the framework is not consistent with how it classifies approaches. A change in the epistemology of an approach leading to variations in how the approach is applied could alter the answers to the questions in the second pillar of the framework. Thus, if the tools from SSM were used in a systems engineering method (Hall, 1962) (e.g. not focussing on facilitation, stakeholder learning or political feasibility), the framework would not classify SSM as a PSM. The researcher would argue that a systems engineering application of SSM is no longer a PSM; indeed it may no longer be SSM. A change to the philosophical assumptions underpinning an approach will alter the approaches' ability to achieve the original aims of that approach. These changes may be incommensurate with the philosophical assumptions required for PSMs and so the classification of the new approach should be different to the classification of the original approach. The inverse is also true for traditional approaches demonstrating softer characteristics. For example, Robinson (2001) built simulation models using facilitation to construct conceptual models of the situation with participants. The conceptual model was then developed using hard simulation techniques. This is not saying that Robinson's (2001) use of simulation constitutes a PSM; merely that the epistemological assumptions underpinning the approach in Robinson's (2001) work are different to those assumed for simulation in

Section 2.4. This may result in the facilitated use of simulation answering yes to more questions in the framework than a purely hard application of simulation. Other examples where a traditionally hard approach may embrace elements of PSMs include Tavella & Papadopoulos (2014) who used VSM in facilitated workshops. The researcher argues that the adaptability of the framework is a strength, not a weakness. PSMs should not be classified based on rigid historic definitions, but should be classified based on the assumptions of the approach in question and how the approach is used. This is rather different to how classifying PSMs have been thought of in the past, but accepting the pluralism with how individuals use approaches and how these changes reflect different ontological, epistemological, axiological, and methodological assumptions may help to solidify what it is that PSMs are and are not.

6.2 Research Question 2: How can PSMs be developed into suitably generic approaches applicable in multiple problem contexts?

The findings from this question identified two novel contributions to the theory of PSM development. First, this project has identified a new way to combine elements of existing methodologies, while maintaining a consistent philosophical set of assumptions. Second, this project has identified how to ensure an approach can be generic to multiple contexts but having two classes of elements. The first of these elements are those which are considered to translate the methodology of an approach and are replicated regardless of context, second are those which adapt to the context. Understanding the presence of these two elements is a novel contribution as it will aid future development of approaches.

These two contributions are considered in relation to the wider literature to identify overlaps and what is new about these findings. This helps to show the novelty of this research project and these findings. They will be structured in relation to discussion points 3 and 4.

6.2.1 Discussion Point 3 considers if smart bits can be used by developers of OR approaches to combine methods without mixing philosophies.

The use of smart bits during development of an approach is presented here as a novel contribution to theory and methodology for the development of new bespoke approaches. Specifically, the thesis argues here that the development of methodology using smart bits is a novel defence to guard against inconsistencies that arise when elements from existing methodologies are combined. This section considers why researchers need an effective defence against these inconsistencies, current defences, and how the smart bit approach provides a better defence than existing arguments. Munro & Mingers' (2002) survey showed practitioners combining a variety of different methodologies during interventions with organisations. This led to a wealth of research into multimethodology aiming to understand how to overcome the philosophical incommensurabilities (Burrell & Morgan, 1979) associated with combining methodologies from different paradigms (Kotiadis & Mingers, 2006; Mingers & White, 2010; Mingers, 2011). Linking or combining different methods or techniques together in a particular intervention is a practice known as multimethodology (Munro & Mingers, 2002). “The essence of multimethodology is to utilize more than one methodology, or part thereof, possibly from different paradigms, within a single intervention” (Mingers & Brocklesby, 1997 p.491). WASAN was originally developed from a combination of analytical tools from academia and tools already accepted within the nuclear context. Schwaninger (2004a) notes the strategy of “mixing methodologies arbitrarily becomes bogged down in incommensurabilities, inconsistencies and incoherence” (p.412). The combination of methods from different methodologies can lead to conflicting assumptions being made about what or how something should be modelled. For example, Question 9 of the four pillar framework asks *'Does the model reflect the different social realities of the participants?'* An approach wanting to take an objective view point where there is an external objective reality which can be captured (such as linear programming) would answer no to this question as different social realities do not exist according to one of the assumptions of that approach; however, the PSMs considered in this thesis would answer yes to this question as they assume problems are socially constructed, thereby implying that different people will understand and view a problem according to their own experiences and perspective and , thus, lead to a different understanding of the problem. The opposing positions between objective modelling approaches and social constructivist modelling approaches would be mutually exclusive within a single methodology. This is because these approaches are from different paradigms; each paradigm differs in terms of the fundamental assumptions they bring to organised inquiry. If there is a combination of methods from different paradigms, then there is a supposed mixing of incommensurable paradigms. This refers to the paradigm incommensurability thesis. There are supposed irreconcilable differences between objectivist (quantitative OR) and subjectivist (PSMs) ontological and epistemological dichotomies; these opposing dichotomies represent opposing competing truths about the world and therefore reconciliation between the two paradigms is problematic (Mingers, 1997). Therefore, researchers must choose the rules under which fundamental assumptions they practices from the various alternatives on offer (Mingers & Brocklesby, 1997).

Several authors have identified ways to guard against the paradigm incommensurability thesis when mixing methodologies in OR. First, some authors have argues that the notion of a paradigm is not so clear-cut and they are 'fuzzy' at the boundary where 'transition zones' exist. Therefore, it is possible to 'build bridges' between paradigms (Gioia & Pitre, 1990). This notion of building bridges or links between paradigms is used in Bennett's Linkage Framework (Bennett, 1985). Ormerod (1995) used the linkage framework to break an intervention into separate stages, only allowing techniques from the same paradigm to be used in each stage. Keeping each method, and therefore paradigm, separate ensures the paradigms are not mixed as each paradigm dominates one phase; the paradigms are not integrated nor used concurrently. The separation of paradigms means that the methods from different paradigms make "practical but not theoretical links" (Ormerod, 1995 p.289). However, using Bennett's linkage framework still leads to problems at a paradigm level. Even if separating the analysis into different phases prevented the paradigms from mixing, the knowledge created using one set of epistemological assumptions is still passed through phases of analysis operating under different sets of assumptions. Therefore, this could lead to the type of data and knowledge created in one phase of analysis not being recognised in latter stages of analysis. Therefore, Bennett's Linkage Framework is not a sufficient defence against the paradigm incommensurability thesis when mixing methods from different paradigms.

Other authors have advocated pluralist paradigms; pluralist paradigms recognise the ability to have multiple paradigms in one intervention. For OR, both Critical Systems Thinking and Practice (CSP) (Jackson, 2010) and Total Systems Intervention (TSI) (Flood & Jackson, 1991) are pluralist paradigms. CSP aims to "learn about and harness the various systems methodologies, methods and models so that they can best be used by managers to respond to the complexity, turbulence and heterogeneity of the problems situations they face" (Jackson, 2010 p.136). Jackson (2010 p.137) says that "the difficulties associated with multimethodology practice can be managed if an initial choice of 'dominant methodology' is made to run the intervention, with a 'dependant' methodology (or methodologies), reflecting alternative paradigms, or view, in the background". Although this choice of dominant paradigm better guards against incommensurabilities, the notion of mixing paradigms will still lead to inconsistencies in research. The dominant paradigm will supersede the other paradigms if there is a conflict. However, as the incommensurabilities appear when there are mutually exclusive assumptions made between the two combined paradigms, stipulating one dominant paradigm does not solve issues regarding inconsistencies within the researcher process. It confounds them as the subordinate paradigms are automatically assumed to be incorrect; there is an explicit contradiction of philosophical assumptions between paradigms in the methodology.

Third, authors argue that it is not necessary to accept that a research method is wholly internal to a single paradigm (Mingers & Brocklesby, 1997; Smaling, 1994). "It is quite possible to disconnect a particular method from its normal paradigm and use it, consciously and critically, within another setting" (Mingers, 1997 p.14). The focus is not only on the technique but also the overarching objectives and theoretical underpinnings and how these support one another (Ackermann et al., 2011).This approach characterises the development of WASAN during this research project. A common WASAN philosophy was identified, which remained consistent in relation to ontology, epistemology, and axiology throughout all stages of the intervention. Smart bits from other approaches were then identified and detached from their existing philosophical paradigm and used within the WASAN philosophy to achieve the stated goals of the methodology. This implied that during the development of WASAN into a generic approach, individual smart bits could be developed in isolation without affecting the rest of the approach. For example, Stage B1, External Analysis, did not have to use all keywords from the waste management hierarchy (WMH) as used in the original approach. Only a subset of the original keywords were appropriate for *Call Handling*—'Avoid' and 'Minimise'. Changing the keywords used during the analysis didn't affect the validity of WASAN, nor would it if all keywords from the WMH had been dropped and replaced with an alternative set of keywords. Provided new developments are in keeping with the WASAN philosophy the smart bits can be adapted to suit the intervention. The smart bit approach to methodology development gives developers the flexibility to identify and develop an approach without risking calls that their research is invalid due to inconsistencies within the different philosophical assumptions made by individual elements of their approach. As WASAN is developed with a common consistent philosophy, it is argued here that it is not multiparadigm or multimethod; the assumptions relating to philosophy do not cross paradigm as they are fixed. The different tools and methods used within WASAN may originate from an array of different methodologies, but they are now assimilated into a new single methodology.

The smart bits approach to methodology development makes a novel contribution to the theory and methodology of PSM development. It is a new way of developing approaches that allows developers the freedom to explore different combinations of smart bits within an approach and providing a defence against the paradigm incommensurability thesis. The flexibility of developing new approaches to suit the requirements of a problem context should be explored further; therefore, research into developing new and existing approaches using smart bits is a proposition for future research.

6.2.2 Discussion Point 4 considers if for an approach to be generic it must have methodological elements which are replicated regardless of context and contextual elements which adapt the methodology to the context.

The findings identified two classes of elements within the WASAN methodology which were required for the approach to be generic. By generic, it is implied that the approach was applicable in a variety of problem contexts without need for further methodological development. Generic does not mean applicable to all problem contexts and all situations as SSM or linear programming are not generic to all problems. The first class of elements identified in WASAN was those elements which were constantly replicated regardless of context; these were termed methodological elements. The methodological elements provided the structure of WASAN; it is through these elements that the WASAN philosophy is implemented into practice. The second class of elements identified in the research were contextual elements; these allow WASAN to be applicable to the local context by adapting to the problem context, thereby bridging the gap between the problem context and the methodology. This discussion considers these two elements further by discussing findings from the further study. Methodical elements requiring consistent replication and contextual elements were identified in Findings 1; however, we can gain a deeper understanding about these two elements by considering additional evidence from the further study reported in Findings 2.

The first element considered is the use of keywords in Stage B1. Discussions with the system owners before Stage B identified that of all the keywords from the waste management hierarchy, only ‘Avoid’ and ‘Minimise’ would be appropriate to use during B1 (Analyse External Operations), replicating those from *Call Handling*. Although keywords were identified in Section 4.4 as a contextual element which can be adapted to fit the context the same keywords from *Call Handling* were chosen by the system owners from *Switchboard, Crime Desk, and Crime Admin*. This could be attributed to the replication of waste across the further study. Further evidence that the waste (not context) which influences the appropriate keywords is *Crime Admin*, where the Channel In was markedly different from the other three systems. In *Call Handling, Switchboard, and Crime Desk,* the main Channel In analysed were phone calls (either from the public or internally). In *Crime Admin,* the main Channel In was the C1 forms which enter the system-in-focus and create waste in a very different way from phone calls.

The second consideration is how none of the methodological elements developed and identified in the Call Handling Study required any further development for them to be applicable in any of the three further systems.

6.2.4 Summary for Research Question 2

This section has considered how PSMs can be developed to be suitably generic to be applicable in multiple contexts. This question identified two novel contributions: First, how the notion of smart bits can be used to develop methodologies while guarding against the paradigm incommensurability thesis. Second, how for an approach to be generic it must have two classes of elements.

With respect to smart bits, authors such as Burrell & Morgan (1979), Mingers (2001), and Schwaninger (2004a) have noted how mixing methodologies becomes bogged down in incommensurabilities, inconsistencies, and incoherence. This can result in claims that knowledge created using these approaches somehow lacks rigour and lead to disputed research findings. The smart bit approach provides a way to detach methods from their previous philosophical assumptions and combine them into a new approach that makes consistent philosophical assumptions and acts as a defence against the paradigm incommensurability thesis.

Second, this section has identified how for an approach to be generic it must have two classes of elements. First are those elements which remain rigid; these do not change regardless of context and are considered those elements which translate the philosophy of an approach into practice. The chapter identified how data from Chapter 4 was supported by additional data from Chapter 5.

6.3 How can an approach show it has the defining features of PSMs??

One of the major weaknesses of the existing definitions of PSMs is how the research community is able to accommodate new or recently developed approaches and consider how the evidence adds value to the existing body of PSMs. Existing definitions of PSMs do not easily show why or if a newly developed approach is or is not a PSM. This section presents the four pillar framework as a novel contribution to theory and methodology of PSMs as it provides a clear way to understand which features of PSMs an approach exhibits. To show the need and novelty of this contribution, this discussion considers how other qualitative approaches have justified their inclusion within the 'PSM family', thereby showing that the four pillar framework offers a more rigorous, usable, and purpose-built approach to identifying the presence or absence of PSM features within an approach.

Table 1 from the Introduction identified eight publications introducing qualitative OR approaches post 2000. In these papers, General Morphological Analysis, Visioning Choices, DPSIR, and Issues Mapping all made claims to be PSMs or similar. First, this section reviews how each author justified this position and then evaluates them all based on the rigour of the definition of PSMS and the transparency in against the four pillar framework.

Ritchey (2006) identifies a number of features of General Morphological Analysis (GMA) that are present in PSMs. These include iterative steps or phases, facilitated group interaction, building shared concepts, collective creativity, identifying important dimensions of a problem context to build a solution space, and dealing with 'wicked problems' or 'social messes'. Subsequently, additional features of PSM, as identified by Rosenhead (1996), are introduced to use as a comparison with GMS; these were that PSMs should

- accommodate multiple alternative perspectives rather than prescribe single solutions;

- function through group interaction and iteration rather than back office calculations;
- generate ownership of the problem formulation through transparency;
- facilitate a graphical (visual) representation for the systematic, group exploration of a solution space;
- focus on relationships between discrete alternatives rather than continuous variables;
- concentrate on possibility rather than probability.

In relation to these features of PSMs based upon the case study, Ritchey (2006 p.803) concludes that “Computer-aided morphological analysis is fully attuned to these criteria and can be seen as an important complement to other PSMs employing hierarchic structures and causally directed relationships.”

O’Brien & Meadows based the inclusion of Visioning Choices as a PSM by comparing a case study of using Visioning Choices with six common characteristics of PSMs identified in Bennett & Huxham (1982) and Rosenhead & Mingers (2001). The six characteristics are given below:

- Their aim is to aid understanding of the situation, rather than provide a single definitive answer to a problem.
- They help the user to look at a situation in a new way.
- The process is considered to be as important as the end product.
- The participation of multiple actors with a plurality of views is often required.
- They focus on perceptions and opinions, rather than being reliant on hard data.
- An analytical component, typically qualitative in nature, is often present.

O’Brien & Meadows (2006 p.575) justified the inclusion of Visioning Choices in the PSM family stating that “Thus it appears that the Visioning Choices methodology compares well with existing PSMs as it shares a number of characteristics in common."

Gregory, Atkins, Burdon, & Elliott (2013) tentatively address if DPSIR can be considered a PSM in their paper by questioning how DPSIR and PSMs are realised in practice. They identify that "the literature reveals a broad range of practice and interpretations of what counts as a PSM" (p.563). However, we define PSMs at three levels: first, characteristics of PSMs; second, the process of PSMs; and third, the epistemology of PSMs. The characteristics of PSMs are drawn from Mingers & Rosenhead (2004); these were that PSMs

- enable alternative perspectives to be brought into conjunction;
- are cognitively accessible to participants from a range of backgrounds and without specialist training, so that the developing representation can inform a participative process of problem structuring (hence the value of conceptual and illustrative models);
- operate iteratively through the problem representation being adjusted to reflect the state and stage of discussion among the participants, and vice versa;
- allow partial or local improvements rather than requiring a global solution, which would imply a merging of the various interests.

Looking beyond these characteristics, Gregory et al. (2013) focus on the similarities between the process of DPSIR and the process of PSMs citing how Mingers & Rosenhead (2004) suggest the above characteristics of PSMs are achieved through modelling. In addition to this, comparisons are drawn between the process of DPSIR and PSMs as a design science (Keys, 2007) and how they both use conceptual modelling (Rouwette, Vennix, & Felling, 2009). The final layer of proof from Gregory et al. (2013) identifies that both DPSIR and PSMs have an epistemological view of social constructivism and, consequently, it can be argued that they both focus on models as heuristic devices to facilitate engagement, explication of knowledge, communication and understanding among researchers, policy-makers, and other stakeholders.

Cronin, Midgley, & Jackson (2014) present Issues Mapping as a PSM; the paper presents features of PSMs identified in the literature. First, they identify that PSMs start from the assumption that problems are multi-perspective (Jackson, 2006) and that improvement of the problem depends on effective framing of the situation (Churchman, 1970). PSMs do not focus upon optimisation (Checkland, 1985b) and differentiate themselves from other approaches in that they used models as transitional objects to structure engagement (Eden & Sims, 1979). These features are used to set the context of the research and identify to the reader what a PSM is. To justify the classification of Issues Mapping as a PSM, the paper evaluates the strengths and weaknesses of the approach as a PSM based on reflections of an application of Issues Mapping's in the context of New Zealand's genetic engineering debate. Their reflections centred around three constructs. First, how Issues Mapping supports constructive engagements of participants' emotions. Second, the use of models in Issues Mapping as heuristic devices. Third, how their application of Issues Mapping connected with organisational decision making on genetically engineered technologies.

The evidence presented to show that GMA, Visioning Choices, DPSIR and Issues Mapping are PSMs show a lack of clarity and transparency in the process used, thereby resulting in a lack of rigour and leave the claims open to challenge. Both GMA and Visioning Choices identify a set of characteristics from one or two sources in the literature, stating that their approach satisfies their identified criteria. There are two problems with justifying that an approach is a PSM this way. First, in both cases, the criteria identified were not presented by the original authors as an exhaustive list of attributes for PSMs; therefore, only selecting these criteria without identifying and closing gaps in the definition shows a lack of rigour. Second, there is little evidence showing how and where the approach maps onto the definition. This shows a lack of transparency in the definition.

For DPSIR, a more comprehensive list of sources is used to identify what is a PSM. These definitions address PSMs in terms of characteristics, process, and epistemology with comparisons with DPSIR at all three levels. In addition, features of PSMs are also compared to a comprehensive definition of complex adaptive systems (which DPSIR was developed to address). This justification shows more rigour in the development of a definition of PSMs; however, there is still no attempt to show that the definition is comprehensive. While there is a clear comparison between the PSMs and the complex adaptive system, there is less transparency in the comparison between PSMs and DPSIR.

Finally, for Issues Mapping, the initial defining characteristics of PSMs are not organised to create a definition for comparison with the approach, only to set the context of the researcher. During the comparison of Issues Mapping with PSMs, the three selected constructs are chosen with little justification of why they are an appropriate definition of PSMs or how they encompass all important elements of PSMs. In addition, the comparison between Issues Mapping PSMs and the three identified constructs were unclear.

Overall, none of the papers presented a wholly convincing argument that all the features of PSMs were present in their approach. First, there was a lack of proof that the comparison was against an exhaustive definition. Second, there was a lack of transparency showing how the comparison was made between the definition and the approach under examination. These two issues could be attributed to two factors: first, there is no agreed method for making a comparison between a developing approach and the existing PSMs. As identified by Gregory et al. (2013), the literature reveals a broad range of practice and interpretations of what counts as a PSM. Therefore, comparison between the authors approach and an agreed definition of PSMs was impossible. Second, in many cases, the main purpose of the paper was not to present the approach as a PSM. Therefore, this influenced the framing and content of the paper.

The four pillar framework is able to help with both these issues. First, the definition has shown to be comprehensive, identifying questions based on four wide-reaching philosophical assumptions of PSMs. Second, the format of the framework makes a comparison to any fringe PSM relatively simple and transparent. To demonstrate these points, the following section will consider Discussion Point 6 which is related to the application of the four pillar framework to another fringe PSM to evaluate the case that the approach is a PSM and the ease of operationalising the framework in this manner.

6.3.1 Discussion Point 5 considers if the four pillar framework can be applied to other fringe PSMs to strengthen their case for inclusion alongside the existing set of PSMs.

To understand if the four pillar framework is able to identify if the features of PSMs are present in other approaches beyond WASAN, the discussion now evaluates Visioning Choices using the framework. Visioning Choices was selected to be evaluated using the four pillar framework over the other three approaches discussed above for pragmatic reasons. The presentation of the approach in O'Brien & Meadows (2006) seemed more transferable to the four pillar framework than the other three approaches. That is not to say that the features of PSMs in the four pillar framework were more or less likely to be identified in Visioning Choices than the other approaches; however, the structure and content of the paper made it easier to search for evidence to answer each of the 15 questions.

To apply the four pillar framework to Visioning Choices, the paper by O'Brien & Meadows (2006) was searched for clear assertions that identify the characteristics for each question. Where a clear statement or figure was identified confirming the presence of that feature, its position was logged. Where clear evidence could not be found, Visioning Choices was assumed not to have that feature of PSMs. Figure 40 shows the answer to each question along with where in the paper the evidence for this can be found.

Pillar 1: System characteristics			
Q1 Does the approach draw an open boundary around the system? Q2 Does the approach understand there are systems as different hierarchical levels? Q3 Does the approach build a qualitative model? Q4 Does the modelling approach try to manage complexity? Q5 Does the approach model an identifiable system?			
Question	Answer	Reference	Justification
Q1	Yes	p.560	Visioning scenarios focus on issues the organisation has control of.
Q2	Yes	p. 557	A vision as described higher order system to judge and review strategy.
Q3	Yes	p. 573	Representations are consistent with Pidd's definition of a model.
Q4	Yes	Table 2	No evidence of reductionist thinking, the stages hold onto complexity.
Q5	Yes	Table 2	The model built represents an action orientated vision.
Pillar 2: Knowledge and involvement of stakeholders			
Q6 Does the approach build a model in a facilitated way? Q7 Does the approach focus on participants learning about the problem? Q8 Does the approach aim to produce politically feasible solutions over optimal solutions?			
Question	Answer	Reference	Justification
Q6	No	p.571	Facilitation is discussed but not in relation to model building.
Q7	Yes	p. 559	Benefits of participation include learning about the situation.
Q8	Yes	Stage 7	Stakeholders are invited to commit to implement specific actions.
Pillar 3: The values of model building			
Q9 Does the model reflect the different social realities of the participants? Q10 Is the model building process generic so it can be transferred to multiple problem contexts? Q11 Does the approach rely on showing procedural rationality to show reliability in outcomes? Q12 Does the model build a validated audit trail of the decision making process?			
Question	Answer	Reference	Justification
Q9	Yes	Stages 4 & 6	Stages 4 & 6 integrate different stakeholder group's visions.
Q10	No	-	Multiple case studies need to be reported here there is only one.
Q11	Yes	p. 574	Organised visioning approach builds an effective group-based process.
Q12	Yes	p. 599	Stakeholder involvement and documentation leads to audit trail validation.
Pillar 4: Structured analysis			
Q13 Does the approach structure knowledge through different stages of analyses? Q14 Are there distinct phases for divergent and convergent thinking? Q15 Does the approach manage knowledge through the methodology to avoid 'Knowledge Leaks'?			
Question	Answer	Reference	Justification
Q13	Yes	Table 2	Table 2 shows the 7 different stages.
Q14	Yes	Table 2	Stages 3 & 5 are divergent while stages 4 & 6 are convergent.
Q15	Yes	Table 2	Learning is carried through the process through documentation.

Figure 40 An examination of Visioning Choices using the four pillars of PSMs

Figure 40 shows that the majority of the features of PSMs from the four pillar framework could be identified in Visioning Choices. This shows that, broadly speaking, visioning choices as used in the paper analysed shares similar assumptions relating to ontology, epistemology, axiology, and methodology with PSMs. The only two questions not confirmed as answering positively based on the evidence present within the paper were *building a model using facilitation (Q6)* and that the *approach is suitably generic to be used in multiple contexts (Q10)*. As the paper was written based on the application of a single case study, a negative answer to Q10 is to be expected as there was no opportunity within the paper to show applicability beyond the case context. With respect to Q6, O'Brien & Meadows note that facilitators are present but their focus is on ensuring that the process and timings are being followed. They present that this is a 'hands-off' approach to facilitation as the group size in the case study was too large for the two facilitators. Issues of facilitation are identified as future research topics. To validate these findings, the researcher sent Figure 40 to Frances O'Brien for her comments. She agreed that in the case study described in their paper, facilitation was not used to build the model; however, she noted that in smaller groups, facilitators could and most likely would be used to build the model. She also agreed that the paper only related to one case study and so with this bound had to answer 'No' to Question 10.

Visioning Choices not answering yes to all 15 questions in the framework is not taken as evidence that Visioning Choices is not a PSM. The only source of data used in answering these questions was the paper by O'Brien & Meadows (2006). For an adequate comparison, this process should be completed by someone with practical and theoretical experience using the approach. Their focus in writing the paper was certainly not to demonstrate answers to all 15 questions from the four pillar framework. Therefore, the emphasis and context of the paper cannot be taken as a definitive information source to search for the answers to the 15 questions.

What the application of the four pillar framework on Visioning Choices has shown is the framework is applicable outside of WASAN.

This way of showing if an approach has the defining features of PSMs appears more rigorous and transparent than the approach originally adopted in O'Brien & Meadows (2006). However, only basing the identification of defining features of PSMs on one paper is not a sufficient data source. Therefore, a proposition for future research identified in this section is to identify the features of PSMs using the four pillar framework in a fringe PSM during practical first-hand research.

6.3.2 Research Question 3 Summary

There is no accepted method to identify if an approach exhibits all the required features of PSMs. Where previous authors have attempted to present a case for their approach to be considered a PSM, they have often been inconsistent, only drawing from one or two sources to base their decision criteria on. The operationalisation of these definitions to identify an approach as a PSM is often inconsistent with authors not being able to always offer clear arguments for how and why their approach exhibits the required features.

The application of the four pillar framework to WASAN, and subsequently Visioning Choices, shows a clear rigorous method for identifying the features of PSMs in a newly developed approach. The 15 features were identified across a range of literature and relates directly to the underpinning assumptions of PSMs; moreover, the framework can be operationalised without too much difficulty. Each of the questions in the framework should be relatively straightforward to answer and can be clearly shown, as in Figure 40. Therefore, this thesis suggests that the four pillar framework offers a novel contribution to PSMs by identifying a clear and transparent way of identifying if the defining features of PSMs are present within an approach.

6.4 Research Question 4: Can philosophical, theoretical, and methodological contributions identified in one PSM be shown as relevant in others, thereby revealing a common framework?

If PSMs make common assumptions relating to philosophy, theory, and methodology, then theoretical contributions related to those assumptions should be transferable across different PSMs. In the further study at the UK Police Force, a new tool in model building was identified in WASAN. This section considers the transferability of this tool across the established PSMs. If this can be shown, then it will first show that there is a commonality within the framework underpinning PSMs. Second, it shows that WASAN shares this common framework, adding weight to the argument that WASAN is a PSM.

6.4.1 Discussion Point 6 considers if modelling a horizontally expanded system constitutes a new type of recursion.

To understand more about the behaviour of waste within *Customer Contact* at the UK Police Force, the research project embraced the doctrine of expansionism (Ackoff, 1979b) by individually modelling multiple linked systems and then analysing them at the meta-system. The aim was to identify actions to reduce the impact of waste across the expanded system that could not be identified through separate analysis of the individual systems. To set the discussion of this type of analysis within a broader OR context, the researcher conducted a literature review to identify the originality of modelling the expanded system, as described in Chapter 5. The most common theory relating to the relationships between different modelled systems in OR is the notion of recursion. Recursion is used to explain how real world systems are “embedded in other more comprehensive systems” (Leonard, 2000 p.711). Figure 41 from Leonard (1999) shows how different recursive systems can be identified in all types of real-world entities. In Figure 41, systems further from the centre are at a higher level of recursion than those in the centre. For example, the $National\ Organization\ System\ (System^{NO})$ will contain multiple nested $Region\ Organization\ System\ (System^{RO})$. It is possible to zoom in from $\mathrm{System}^{\mathrm{NO}}$ to a single $\mathrm{System}^{\mathrm{RO}}$ using recursion as a tool to help us think about the relationships between these systems. However, in these examples recursion is thought about vertically, with the relationship of systems considered across different hierarchical levels. In the further study, the expanded system was conceptualised horizontally to include the analysis of upstream and downstream systems to fit with how WASAN views the flow of waste. The relationship between the systems analysed was not vertical but horizontal with all systems sitting on the same horizontal plane. This Discussion Point reconceptualises recursion into a tool to help represent both vertical and horizontal relationships between systems. This development will provide a new contribution to the theory and methodology of WASAN and PSMs.

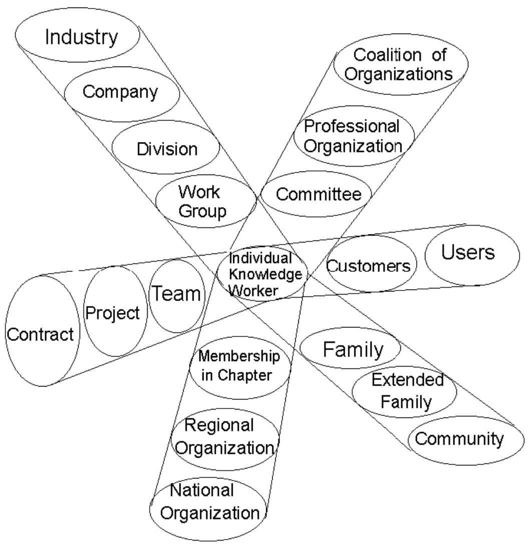

Figure 41 Vertically recursive systems (from Leonard, 1999)

To explore how recursion could be reconceptualised beyond only applying to vertical relationships and representing horizontal systems, this Discussion Point first identifies the theoretical principles of recursion through a review of the literature from which three requirements for recursion are derived and compares them with further study; second, it shows the difference between vertical and horizontal recursion. As a result of these findings, the chapter develops discussion points which expand the implications of horizontal recursion beyond WASAN and this project to other PSMs; these discussion points are considered in Chapter 6 of this thesis.

Theoretical context of recursion

To understand recursion, the project examines its meaning in three alternative contexts—geometry, linguistics, and computer science—and then reviews the use of recursion in VSM. The aim of this literature review is to extract the key principles of recursion from different contexts to establish a definition of recursion. These principles are expanded into criteria to judge if a model building approach has employed recursion. Once this is established, the project will employ the definition to demonstrate that modelling the expanded system in the further study constituted a new type of recursion.

Recursion in geometry

In geometry, shapes and curves can be defined recursively, an example being Koch's (1906) curve [Figure 42]. As Falconer (2003) describes, “We let E_0 be a line segment of unit length. The set E_1 consists of the four segments obtained by removing the middle third of E_0 and replacing it by the other two sides of the equilateral triangle based on the removed segment. We construct E_2 by applying the same procedure to each of the segments in E_1, and so on. Thus, E_k comes from replacing the middle third of each straight line segment of $\mathrm{E}_{\mathrm{k}-1}$ by the other two sides of an equilateral triangle thus giving a recursive definition”. (Falconer, 2003 p.xviii). The recursion stops and the final shape is drawn when a pre-defined stopping criterion is met.

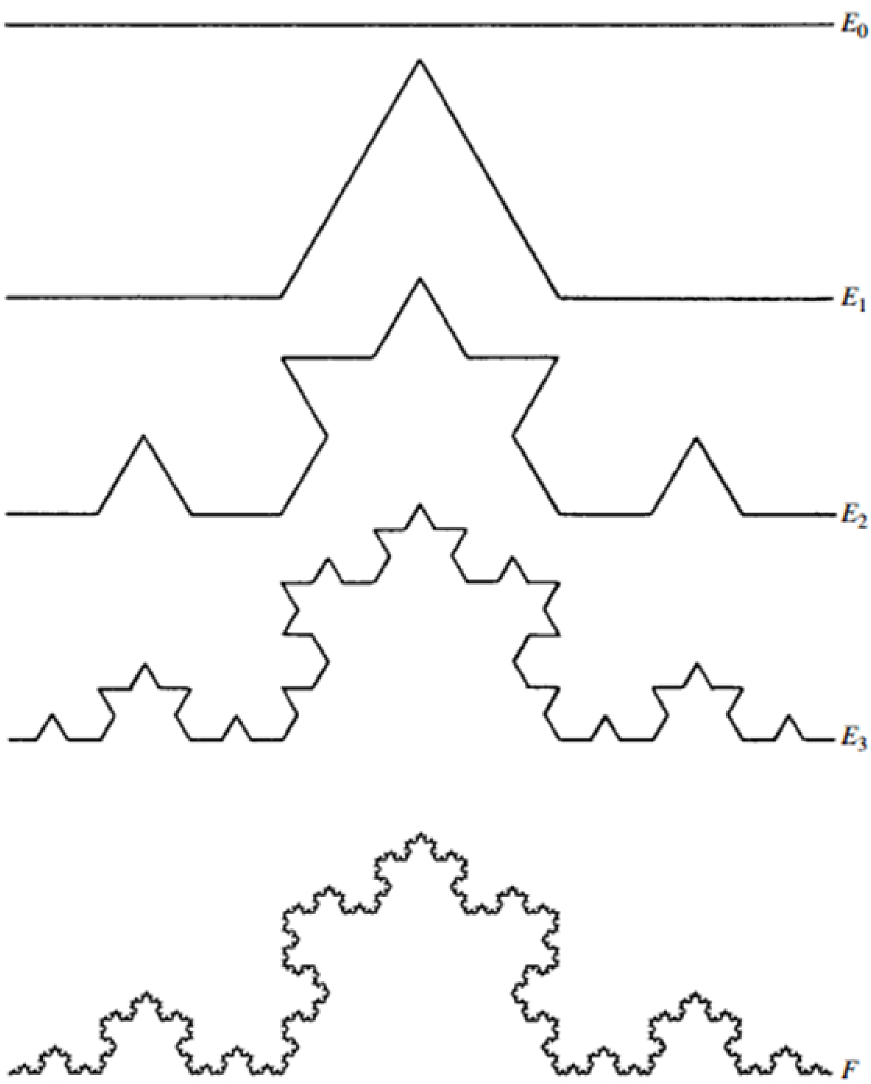

Figure 42 Koch Curve (adapted Falconer, 2003)

The curve is used as the basis for the shape 'Koch Snowflake' [Figure 43]. Each line of a Koch snowflake is altered recursively to build the shape. "We begin with an equilateral triangle S_1 of side length one, which has a perimeter $p_1 = 3$, and an area $A_1 = \frac{\sqrt{3}}{4}$. The next step in the process is to create a new shape S_2 by selecting the middle third segment of each of the three sides from S_1, detaching one end of each segment and swinging them out from the triangle at an angle of 60°, then filling in the gaps with a congruent segment so as to form equilateral triangles on each side of S_1. Thus, each of these three new smaller equilateral triangles have side length of $\frac{1}{3}$. The perimeter $p_2 = 4$ and area of S_2 is then $A_2 = \frac{\sqrt{3}}{3}$." (Dence, 2000 p.245).

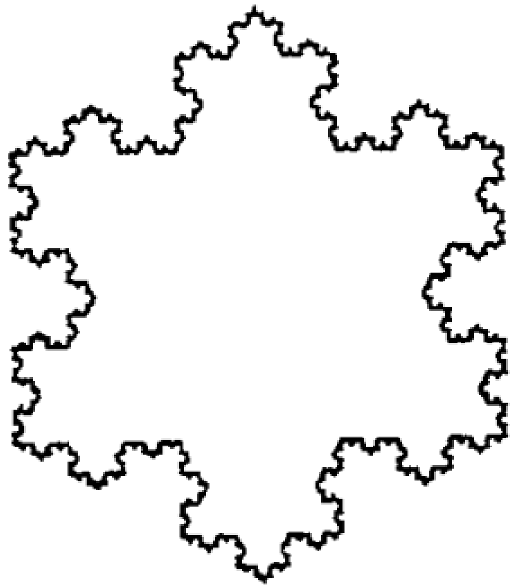

Figure 43 Koch's snowflake S^5 (adapted Falconer, 2003)

These shapes are too irregular to be described by Euclidian geometric language so they are described recursively. However, there is no hierarchical insinuation here; instead they build the curve on the same horizontal plane, thereby demonstrating horizontal recursion of a continuous sort until the stopping criterion is met. Many other geometric examples exist, including the Sierpinski triangle or gasket which is obtained by repeatedly removing (inverted) equilateral triangles from an initial equilateral triangle of unit side-length (Sierpiński, 1915).

Recursion in linguistics

Recursion in linguistics refers to particular sentence structures or grammars that are seen in human languages. Originally called self-embedding by Chomsky (1959), he described how the ability to embed sentences within one another provides unlimited context and therefore differentiates human language from that of animals (Hauser, Chomsky, & Fitch, 2002). Sauerland & Trotzke (2011) describe a recursive sentence structure as one where string C can be derived from C of a string that properly contains C, that is, C is preceded and followed by two non-trivial strings. A classic example of recursion is the children's rhyme 'The House that Jack Built', where each new element of the sentence is embedded as a string within the previous iteration:

'This is the house that Jack built.
This is the malt that lay in the house that Jack built.
…
This is the horse and the hound and the horn; that belonged to the farmer sowing his corn,
That kept the cock that crowed in the morn; that woke the priest all shaven and shorn,
That married the man all tattered and torn; that kissed the maiden all forlorn,
That milked the cow with the crumpled horn; that tossed the dog that worried the cat,
That killed the rat that ate the malt; that lay in the house that Jack built'.

Theoretically, the rhyme could go on continuously without any stopping criterion, with each new sentence embedding a new string into the previous version. The ability to embed explanatory terms within a sentence (e.g. the addition of the words following 'that' in the rhyme), means that through the use of recursive sentence structures or grammar humans can create any statement without needing infinite words within the language to describe what went before. This was first noted by Descartes (2003 [1637]) who hypothesised that the difference between man and animal is that an animal "never … arranges its speech in various ways … in order to reply appropriately to everything that may be said in its presence, as even the lowest type of man can do." In linguistics, recursion enables 'discrete infinity' by embedding phrases within phrases of the same type, occasionally, but not necessarily, in a hierarchical structure (Sunitha & Kalyani, 2010).

Recursion in computer science

In computer science, a recursive routine is when a function calls itself, that is, where certain operations are continually repeated with the output of each repetition used as the input of the next repetition until some stopping criterion, or 'base case', is reached and the final value is obtained (Seitman, 1991). A recursive function is defined in terms of itself (Sunitha & Kalyani, 2010). A simple recursive program can be used to calculate a factorial where the factorial '$n!$' is the product of all positive integers less than or equal to n. Below is a recursively defined program to compute n factorial $(n!)$.

```
IF N= 0
  THEN FACTORIAL = 1
  ELSE FACTORIAL =
  N*FACTORIAL (N- 1)
END
```

Recursive programs deconstruct a large problem into smaller sub-problems. The same subroutine can be called on time and again to solve the problem, and these tend to be easier to program and uses less program code (Seitman, 1991). Computer scientists have specified six types of recursive routines: linear (only calls itself once), binary (calls itself twice or more), exponential (calls itself exponentially), nested (a call to the recursive function is the recursive function itself), mutual (it [function A] calls function B which calls function C which in turn calls function A), and tail (the last thing the function does). Any of these six may provide examples of vertical or horizontal recursion, but it would depend on whether the embedded code is analysing sub-sets (vertically) or continuous sets (horizontally).

Recursion in the Viable System Model

The OR approach most commonly associated with recursive model building is VSM, which is a method that defines the architecture of complex organisations and diagnoses failures that compromise performance (Flood and Jackson, 1991). Watts (2009) notes that recursion is fundamental to VSM as systems are constructed of sub systems that are autonomous, adaptable, self-regulatory, and self-organising. In its recursive structure, “any viable system contains, and is contained in, a viable system” (Beer, 1979 p.118); this portrays a hierarchical view of recursion.

It can be difficult to represent the hierarchical separation of multiple systems in a single model; thus, a VSM model represents one layer, including its connections and interactions with higher and lower recursive levels (Tejeida-padilla & Badillo-pin, 2010). Figure 44 shows different recursive systems, with systems further from the centre being at a higher level of recursion than those in the centre. For example, *The State Economy* ($System^{SE}$) contains multiple *Industries* ($System^{IN}$), so it is possible to zoom our analysis from a meta-system ($System^{SE}$) to a single sub-system ($System^{IN}$) with the output from $System^{IN}$ informing $System^{SE}$, and vice versa. Around each of these systems is a boundary depicting what is and is not included within the recursive level.

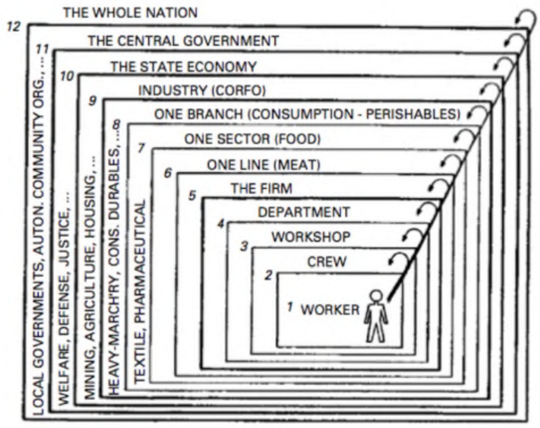

Figure 44 Twelve Levels of recursion in Chile (from Hoverstadt, 2008)

In VSM, recursion goes beyond merely referring to individual hierarchical levels, but includes the replication of organisational structures across each recursive level; this means that the same type of analysis can be performed on each recursive level. Leonard (1999) explains this as the structure of the entire model being replicated in each of its parts and the relationships between the parts, that is, “self-similarity” (Jackson, 2003 p.118). Espinosa, Harnden, & Walker (2008) compare this to Russian dolls, where each doll is contained within a larger doll and contains identical smaller ones. Thus, when analysing recursive levels, exactly the same modelling approach should be applied at each level. The consistent recursive structure enables comparison across an organisation to eliminate inconsistencies (Leonard, 1992) and recursion demands an exact replication of structure in each case (Beer, 1984). For VSM, the same structure is present in all systems; it comprises five sub-systems: S1 Operations, S2 Co-ordination, S3 Control/Monitoring, S4 External Environment, S5 Identity (Beer, 1981). These five sub-systems exist in any viable organisation and should be in balance. “Models depicting these five functions are repeated from smallest part of an organisation which itself could operate as a viable unit to the most inclusive, usually the legal boundaries of the organisation, utilizing the concept of recursion” (Leonard, 1992 p.34). This is the second proposition of VSM: that the viability, cohesion, and self-organisation of an enterprise depends upon the specified units being recursively operating at all levels (Schwaninger, 2004b). For example, the S1 Operations are expected to be ‘viable’ (Bustard, Sterritt, Taleb-Bendiab, & Laws, 2007) and therefore they will possess the same five sub-systems replicated throughout VSM. The recursive systems theorem states “if a viable system contains a viable system then the organisational structure must be recursive” (Beer, 1981 p.228).

By taking the recursive systems theorem to its natural conclusion, it would be possible to build infinite models (Beer, 1984); each VSM would have S1–S5 and a meta-system with the S1 unit or meta-system also fitting the VSM structure. While modelling progressively smaller or larger viable systems theoretically could go on for infinity, for pragmatic reasons it does not; thus, modelling all the systems using the VSM in Figure 44 for the same project would be time consuming and the modeller is likely to achieve diminishing returns rather quickly. A stopping criterion exists when model building becomes unhelpful to understanding the organisation. Jackson (2003) suggests that the stopping criterion has three recursive levels: the ‘system in focus’ (Level 1) as the primary model, the meta-system (Level 0), and sub-systems of the primary model (Level 2). Level 2 is a model of the S1 Operations units in Level 1, which itself is a model of the S1 Operations units in Level 0. To manage the detail of the models in Levels 0 and 2, Beer (1979) introduces the black box from which emerge linkages to Level 1 without overwhelming the analyst with the model details. Here, he identifies two regulatory aphorisms: it is not necessary to model the black box to understand the nature of the function it performs (p.40), and it is not necessary to model the black box to calculate the variety that it may generate (p.47). Thus, black boxes ensure that analysts do not need to model all recursion levels in the same depth to be able to understand the system.

Criteria to define recursion

From reviewing these four contexts, there are three common conditions that must be met for something to be considered recursive. First, there must be consistent replication; second, recursion must be self-referencing or self-generating; and, third, the recursive operation must be aggregated given an increased understanding of a problem/situation than if it were from a single iteration of the recursion.

On constant replication, in geometry, the shape is created by repeating the same procedure over and over again; for example Koch's curve E^k is made of four smaller Koch curves of E^{k-1}, but a third the size of E^k. In linguistics, a recursive sentence structure is replicated within another sentence. In computer science, the same program code is repeated to solve the problem until the goal of the problem is reached. In VSM, the structure of the same five sub-systems (S1–S5) is repeated throughout the entire organisational system (and beyond).

On recursion being self-referencing or self-generating: In geometry, the recursive shape (S^n) is based on the previous iteration of the shape (S^{n-1}), so it will have to be generated by reference to the previous shape in the sequence. A recursive linguistic structure is one that can be naturally generated by a recursive program. In computer science, the recursive program is defined in terms of it calling itself until a stopping rule is reached. A VSM Level 1 model references the Level 2 models through the S1 Operations units; indeed, Level 1 is a model of an S1 Operation that is referenced in the Level 0 model.

On the recursive operation being aggregated to provide an increased understanding of a problem than a single iteration of the recursion: In geometry, the shape is not generated without the recursive steps, that is, it is not possible to derive Koch's snowflake S_5 without the previous four iterations. In linguistics, recursion gives us context, that is, it is possible to include context in our answers; questions do not require an infinite set of words. In computer science, only by completing the recursive program can you obtain the answer to the problem it solves. In VSM, constructing Level 2 models of S1 Operations units uncover detail, while modelling the meta-system in Level 0 increases the breadth of understanding.

These three criteria align with the definition of 'recursive' by Oxford Dictionaries (2014): "The repeated application of a rule, definition or procedure to successive results". Below these criteria are used to consider horizontal recursion as a complement to vertical recursion.

Horizontal Recursion—definition of horizontal recursion

The vertical recursion in Figure 44 does not explain the widest range of problem contexts that PSMs may need to model, for example, it misses the interrelationships between multiple systems on the same hierarchical plane. To explain using Figure 44, a *Firm (F)* is comprised of three sub-systems called *Departments (D)* which work together to ensure that the Firm is viable, assume these are *Marketing (MK)*, *Finance (FI),* and *Operations (OP)*. These three interacting *Departments* can be represented as vertically recursive under *System*^{F}, as illustrated in Figure 45.

However, using vertical recursion to uncover how the actions of one of these departments have implications for other departments does not reflect the relationship between systems. To explain, *System*^{MK} could be modelled *(Model*^{MK}*)* using a PSM, but *System*^{MK}, *System*^{FI}, and *System*^{OP} are not organised hierarchically; thus, any vertically recursive approach based on Figure 46 would provide an incorrect representation of the situation and relationship between the systems. Instead, *System*^{FI} and *System*^{OP} are part of the expanded-system environment for *System*^{MK} and so interactions among these systems could be modelled using a black box (Beer, 1979) in *Model*^{MK}. Using a black box does not compromise the integrity of *Model*^{MK}, but shows that there is a relationship or interdependency between *System*^{MK} and the other two systems. Furthermore, as *System*^{FI} and *Model*^{OP} are referenced as black boxes in *Model*^{MK}, the black boxes can be modelled to build *Model*^{FI} and *Model*^{OP} and use the same modelling approach as *Model*^{MK} to readily enable linkages and comparison across models. This shows (1) the need to use the same modelling technique to consistently replicate the analysis across departments and thereby (2) understand how each department affects each other (i.e. self-reference), in order to (3) build an increased understanding of the issues by aggregating the triptych than is possible from analysing just one department. These three points map onto the three criteria for recursion from above. The only difference here from the vertical recursion used in VSM is that the recursive systems are on the same hierarchical plane.

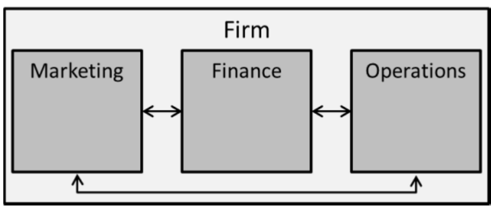

Figure 45 Vertical recursion of a Firm and Departments

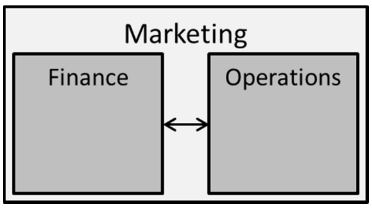

Figure 46 Incorrect use of vertical recursion

Using horizontal recursion to represent *Model*^{MK}, *Model*^{FI}, and *Model*^{OP} on the same hierarchical plane enables their aggregation and an opportunity to explain the interactions between the three models. This builds a model that provides insight to managers in , $Finance$, and $Operations$ as well as the *Firm*. This is not the same as building a single *Model*^{F} at a higher level of vertical recursion; the single Firm-level model is likely to miss the depth of individual sub-systems and the interconnections between the sub-systems as these are irrelevant elements to include in a mode of the *Firm*.

Figure 47 shows how it is possible to build horizontally recursive models if each model conforms to the three criteria for recursion: first, replication of the analytical approach to build each system brings consistency and allows comparison across models. Second, referencing is provided through the arrows in Figure 47 that show users the interactions and when to move from one model to another. Thus, for example, a user would know when to move from *Model*^{MK} to *Model*^{FI}, when *Model*^{FI} is referenced in *Model*^{MK}. Third, moving between models and constructing a meta-systemic understanding of each system allows for the aggregation of models and knowledge. These concepts that describe what is required for horizontal recursion have been explained in theory; the Discussion Point now considers how horizontally recursive model building was present in practice in the further study by looking at the findings.

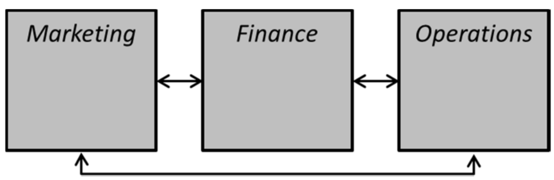

Figure 47 Correct use of horizontal recursion

The findings from the further study identified three elements which are required for modelling the expanded system. These are that all system models must be built using the same methodology and contextual elements. Second, reference another modelled system as a black box, and third, aggregate multiple system models to give additional benefits to the decision makers. These three criteria match those identified above from recursion. Therefore the WASAN models built and aggregated in the further study can be considered recursive.

As Discussion Point 7 identified the combination of models, the further study constituted horizontal recursion for the remainder of the thesis; this type of modelling will be referred to in that manner. This will enable comparison between the horizontal recursion in WASAN and other types of recursion used elsewhere.

6.4.2 Discussion Point 7 considers the generic benefits of modelling the expanded system.

The benefits of horizontal recursion in WASAN are similar to those of vertical recursion in VSM. First, recursion "allows elegant representation of organisations" (Jackson, 2003 p.87). The representation of misrouted calls from the further study [Figure 48] offers more detail of the complexity than a single *Customer Contact model* could represent. Moreover, when systems are linked recursively using the same rules and structure, it is more elegant than mapping each system in isolation. Analysts could build a single large model that encompasses all the expanded systems as one higher order system, but the emergent properties of the individual systems would become more difficult to identify (Tejeida-padilla & Badillo-pin, 2010). Second, according to Beer (1984 p.16), understanding the vertical relationships between systems is key because of "Hegel's Axiom of Internal Relations: the relations by which terms (or in this case, recursions) are related are an integral part of the terms (or recursions) they relate." A system behaves in the way that is does because it is linked to other systems in the ways that it is. Thus, studying the relationships between systems provides more meaning to the systems being studied than if they were analysed independently (the notion of holism). Recursion enables the bounded system to be re-opened (Beer, 1999), thereby meaning that the interdependence of different systems within an enterprise can be represented (Jackson, 2003). As Beer (1989 p.275-276) states, "it is simply the case that you cannot have a successful solution to a systemic problem that does not take its embedments' into account … In short, I advocate study of the meta-systemic embedment precisely because it enables a social system to understand and accept its own responsibilities."

Both horizontal and vertical recursion give tools for modellers to go beyond modelling a single system so they may see how systems are interrelated by issues spanning more than one system.

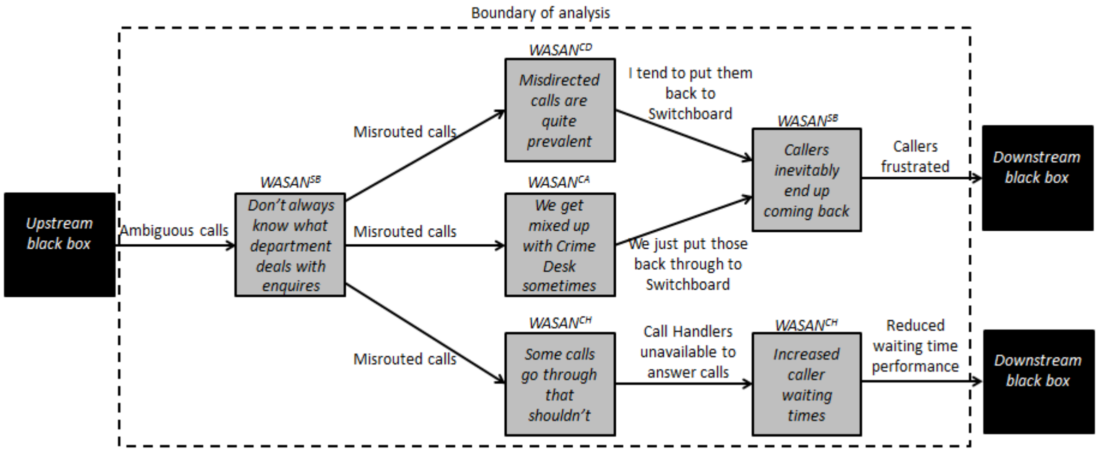

Figure 48 Repeated from Chapter 5

<u>6.4.3 Discussion Point 8 considers if modelling the expanded system is applicable to PSMs beyond WASAN.</u>

The further study showed the value of horizontally recursive model building brought to the application of WASAN in the UK Police Force. The additional analysis of the expanded-system using horizontal recursion led to new insights that would not have been identified from analysis of the individual systems. This Discussion Point considers recursive model building in relation to the existing set of PSMs. If the principle of horizontal recursion can be identified as useful to the other PSMs, then this shows that research into the theory and methodology of WASAN can also be transferable to the theory and methodology of other PSMs. For this thesis, showing the transferability of such contributions from WASAN to the existing set of PSMs is the final element of proof required to show that WASAN is a PSM.

The further study identified three criteria required to model the expanded system; these same criteria were confirmed as required for recursion from a literature review in Discussion Point 8. Criterion 1 requires consistent replication of methodology; criterion 2 requires that recursive models reference each other; and, criterion 3 requires the recursive models to be aggregated to provide an increased understanding of a problem/situation than if the models were not analysed recursively. This section discusses the translation of these three criteria from WASAN into the established PSMs.

Although recursion (by name) is not present in the established PSMs, the principles of recursion are evident in PSMs. Wilson (1990) uses these principles when building conceptual models from root definitions in SSM; different resolutions are used to define a vertical hierarchy of systems [Figure 49]. Building different resolutions of systems ensures that models do not become too complex and difficult to understand: “Each activity in this first level model can, itself, be defined as a system and, through the mechanism of root definition be modelled.” (Wilson, 1990 p.35). Using a root definition to build a second resolution model is replicating the same methodology used to build the first-level model—criterion 1. The outer system (boundary *X* in the second resolution model in Figure 49) matches the individual activity *X* in the first resolution model. Thus, *System X* in the first resolution can be considered a black box which can also be modelled, and this constitutes self-referencing—criterion 2. Finally, displaying the system models side-by-side as in Figure 49, is an aggregation of data, and this constitutes criterion 3. Wilson's (1990) hierarchical models demonstrate satisfying the criteria for recursion, thereby illustrating vertical recursion in a PSM.

There are also examples of vertical recursion in SODA. SODA aims to understand how a person or group defines an issue. Strategic issues are linked using word/arrow diagrams with an action orientation to produce a cognitive map arranged in a hierarchical teardrop. The hierarchy of the teardrop places goals at the top, strategies to realize those goals in the middle, and actions required to implement those strategies at the base. Multiple individual Level 2 cognitive maps can be used to build a composite group Level 1 model. The individual models collect the "different views and belief sets as individual cognitive maps, drawing together this expert opinion in the form of a composite map which is the aggregation of the cognitive maps representing models of the expertise of each expert … using the composite map in a workshop setting" (Eden & Ackermann, 2004 p.618). Here, the Level 2 models replicate the same data collection technique—criterion 1. The overlaps between Level 2 models are used to stitch the models together to form the composite Level 1 model; these overlaps constitute referencing between the Level 2 models—criterion 2. Finally, for SODA, additional understanding and linkages can be gained from analysing the composite Level 1 model—criterion 3. Figure 50 shows two pseudo individual Level 2 models from Participants A & B. The Level 1 composite model stitches together the two individual models at Nodes 1, 4, and 7, as both participants mentioned those same issues. The process of moving from individual to group maps constitutes a form of vertical recursion.

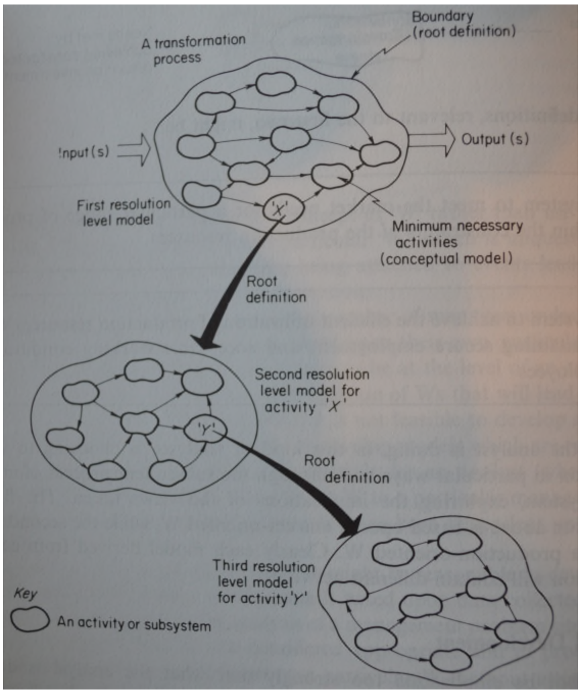

Figure 49 Vertical recursion in SSM (from Wilson, 1990 p.34)

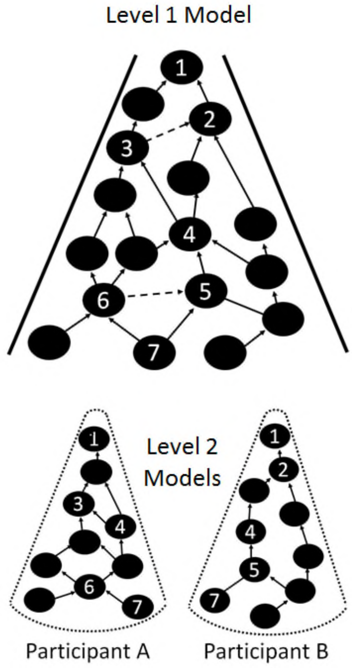

Figure 50 Vertical teardrop (adapted Eden & Ackermann, 1998)

There are also examples of horizontal recursion within PSMs. Figure 51 is an SSM conceptual model that shows the interaction between the *Planning System*, *Marketing System*, *Resource Development System*, *Control System* and *Maintenance System* within *British Airways*. The dotted lines constitute Level 1 system boundaries and contain the Level 2 systems. The solid arrows between processes across Level 1 boundaries show interactions across systems, such as “Negotiate business” from the *Marketing System* interacts with “Decide what facilities need to be developed to meet long-term requirement” from the *Resource Development System*. There are also other horizontally recursive black box systems that are not modelled, such as the arrows pointing off the model to “The technology” in the top right. This metamodel provides more information than the isolated individual Level 1 models, as the interactions within and across systems are shown clearly here. Each model was built replicating the same methodology—criterion 1. Recursive systems are referenced, some of which are modelled, while others are treated as black boxes—criterion 2. The aggregated model provides information beyond a single model—

criterion 3, for example, the interactions between models, emergent properties, and responsibilities of the individual Level 1 models.

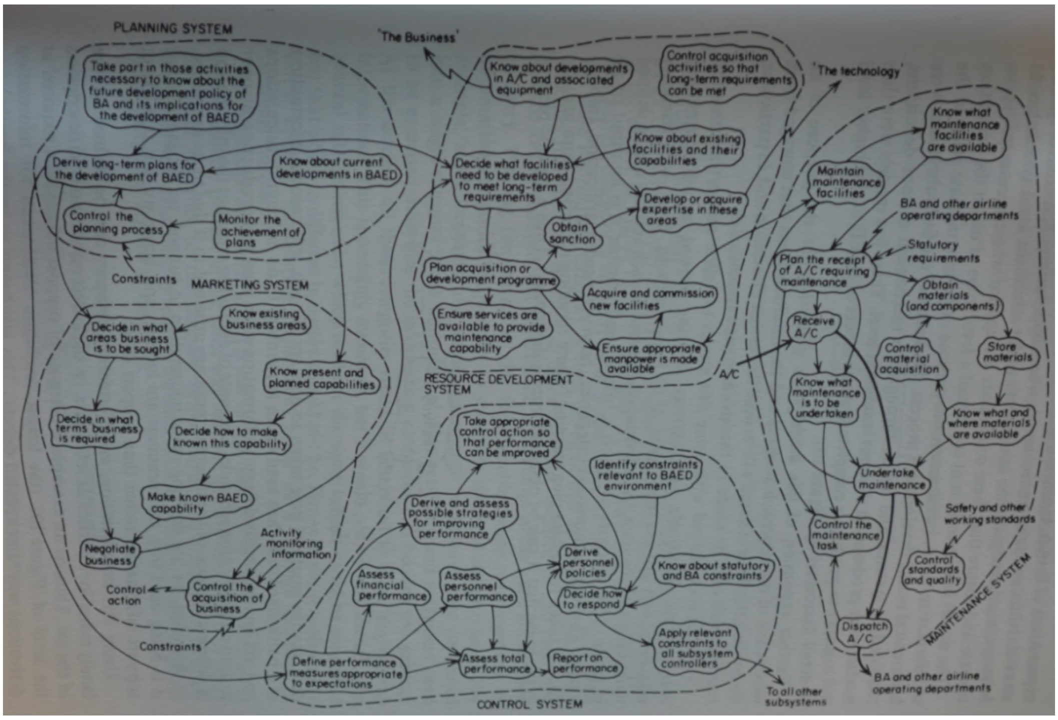

Figure 51 Horizontal recursion in SSM (from Wilson, 1990 p.219)

This shows that the principles of horizontal recursive model building, as identified in the further study, and of vertical recursion can be identified within the two most widely used and researched PSMs.

6.4.4 Summary of Research Question 4

This section has considered the transferability of theoretical contributions among different approaches which have the same underlying philosophical framework. The section began by considering if modelling the expanded system identified in the further study constituted a new type of recursion by considering the common features of recursion across four different contexts. Once this was established, the section considered the transferability of horizontal and vertical recursion as a theoretical contribution from WASAN to other PSMs. This was shown with examples from SSM (Wilson, 1990) and SODA (Eden & Ackermann, 1998). The identification of horizontally recursive model building is a novel contribution of this research. This new approach to model building is able to represent the meta-systemic nature of problems across an expanded system and could prove useful for decision makers and modellers.

The transferability of recursion from WASAN to the other approaches is appropriate to consider, as similar concepts are included within the four pillar framework. Q1 of the framework is concerned with the boundary of the system in focus. Q2 of the framework is concerned with the hierarchy of systems; these two principles are central to horizontal and vertical recursion. Therefore, research into this area for one PSM should be partially transferable to other PSMs.

Showing the transferability of this theoretical contribution identifies two aspects that are critical to the understanding of PSMs and WASAN. First, it shows that there is a common theoretical framework underpinning PSMs; the transferability of the theory indicates that the contribution was not made to WASAN but is a contribution to the framework, which itself is applicable to WASAN and a range of other approaches. Second, it positions WASAN as sharing the same common framework as the established PSMs. This is further evidence of WASAN's status as a PSM.

6.5 Summary of Discussion

The aim of this thesis has been to provide a depth of understanding of the PSMs through a critical analysis of the philosophical, theoretical and methodical position of PSMs. This section briefly pulls together the discussion of the four research questions to provide an answer to the central aim of the thesis. First this thesis has identified defining features of PSMs and collated them into the four pillar framework. Linking the four pillar framework with the four philosophical constructs, ontology, epistemology, axiology and methodology gives a depth of understanding about the philosophy of PSMs.

Next the thesis developed WASAN to understand more about the methodology of PSMs, through this development process the research project identified smart bits as a useful development tool for the methodology of PSMs and how PSMs need both contextual elements and methodological elements to be generic.

Finally the thesis identified horizontal recursion as a tool that can be used in WASAN. Linking this with the underpinning framework of PSMs and showing how the theoretical contribution was transferrable to other PSMs provided a depth of understanding about the theory of PSMs. That is there to some extent a common theory which can be shared. Theoretical contributions made to this theory are transferable to other PSMs. The analysis of PSMs in this way has provided a depth of understanding about the philosophy, theory and methodology of PSMs that has not been covered in the existing literature.

The final chapter of this thesis will review the theoretical contributions this research project has made; review what I as a researcher have learned through this research process; identify the academic papers that can be written as a result of this research project; and, identify new areas of research that have been identified as a result of this project.

Chapter 7

Conclusion

7.0 Introduction

This conclusion chapter addresses four areas; first, it revisits the contributions made by this thesis. Second, it reflects on what has been learnt about the research process and identified some limitations of the research. Third, it identifies the research papers that can be written based upon the content of this thesis. Finally, it highlights the new research gaps that have been identified as a result of this research project.

7.1 Contributions of the thesis

This thesis has sought to critically analyse the philosophical, theoretical and methodological features of PSMs. This was identified as an area where there was a lack of consistency within the literature, so a clear gap existed which could be filled by this research project. In practice the project took an action research approach to develop the methodology WASAN within a context while simultaneously learning about the framework of ideas underpinning the approach. The key areas this research project has contributed to are: Understanding the features of PSMs; development of methodology; horizontal recursion; development of theory across PSMs; and, the development of WASAN. These are all considered below along with consideration of the impact of the research.

7.1.1 Understanding the features of PSM

This thesis has made three contributions to our understanding about the features of PSMs. They are outlined below.

1. *Identifying the key features of PSMs:* One of the key aims of this research was to identify a definition for PSMs. While PSMs have been generally accepted as a family of methods sharing characteristics since they were introduced as such by Rosenhead (1989) a definition of PSMs has not been established. The literature review in Chapter 2 identified 15 features of PSMs which were both rooted in the philosophical assumptions of the approaches but also identified in practice. The 15 questions were developed into the four pillars framework which can be used to identify if an approach has the features of PSMs. Each of the four pillars is aligned to a philosophical construct of ontology, epistemology, axiology and methodology. The features in each pillar were identified in the literature review.
2. *Identification of the concept of knowledge leaks:* While assessing the validity of the four pillar framework this research project identified a new common feature of PSMs which did not appear in the literature, knowledge leaks. This is the way in which a methodology with multiple phases of analysis ensures knowledge is not lost between stages of analysis through misrecording.
3. *Development and classification of PSMs:* The research project showed that the four pillar framework could be used to identify if approaches have the required features to be considered a PSM. The introduction identified that there have been several new qualitative OR approaches developed since 2000, for example Issues Mapping (Cronin et al., 2014). There was no consistent and accepted way for these approaches to show they were PSMs. The four pillar framework gives potential PSM developers the

opportunity to show their approach exhibits the requisite features to be considered a PSM. Chapter 4 operationalised the framework to show that WASAN exhibited all 15 of the features of PSMs. To show the applicability of the framework its use was operationalised again in Chapter 6 to assess if a new PSM, Visioning Choices (O'Brien & Meadows, 2006), exhibited all of 15 features. The framework provides a clear rigorous and consistent way to identify if an approach has the features required to be considered a PSM, thus is a novel contribution to the philosophy, theory and, methodology of PSMs.

7.1.2 Development of methodology

This thesis has made two contributions to our understanding about the development of PSMs. They are outlined below.

1. *Smart bits as a defence against the paradigm incommensurability thesis:* The practice of mixing methods within a single intervention has become increasingly popular (Munro & Mingers, 2002). As the different dimensions of the multi-methodology can address different dimensions of the problem context (Franco & Lord, 2011). However the combination of methods from different methodologies can lead to conflicting assumptions about what or how something should be done. This leads to incommensurabilities and inconsistencies (Schwaninger, 2004a) which can hamper the research process and knowledge creation. This is because of conflicts in the underlying assumptions that underpin the mixed methodologies. This is called the paradigm incommensurability thesis. This project has used the smart bit approach as a defence against this, individual smart bits are detached from the philosophical assumptions associated with the methodology they are taken from and combined into a new approach which has its own consistent philosophical underpinnings. This type of

development was shown in Chapter 4 where elements of WASAN were deconstructed into smart bits such as the waste management hierarchy. The smart bits were developed and then reintegrated into WASAN checking that the underpinning philosophical assumptions hadn't been compromised.

2. *Showing how to develop an approach so it is generic to multiple contexts:* Chapter 4 was concerned with developing WASAN so it was generically applicable to new contexts. During this the research identified two classes of elements which needed to be present within an approach for it to be generically applicable. First are elements that adapt to the context to ensure the approach can translate to the specific problem situation; these were termed contextual elements. Second were elements which were replicated regardless of context, these translated the underpinning philosophy of WASAN and were termed methodological elements. Changing the methodological elements would alter the aims and philosophy of the approach so it could no longer be considered WASAN. Identifying these two classes of elements will help with the future development of bespoke approaches so that they can be used in multiple contexts.

7.1.3 Horizontal Recursion

This thesis has made two contributions to our understanding about how recursion can be used as a tool to help model builders represent interconnected systems. They are outlined below.

1. *Definition of recursion in model building*: Chapters 5 and 6 identified the use of recursion as a tool for model builders. Recursion allow more elegant representation of organisations (Jackson, 2003) and shows the interdependence between different systems within a meta-system (Beer, 1989). The research identified three criteria for recursion these are; first, there must be constant replication of the modelling approach used across all

subsystems; second, the individual system models must reference each other so that the final model can be self-referencing; third, the models must be aggregated to give some greater understanding of the problem that is under consideration. These criteria for recursive model building were shown in WASAN at the further study at the UK Police Force. In the Discussion chapter these criteria were also shown as applicable to SODA (Eden & Ackermann, 1998) and SSM (Wilson, 1990).

2. *Horizontal recursion as a new type of recursive model building*: Recursion in vertically arranged systems has been long established in VSM (Beer, 1972). Chapter 5 identified a new type of recursion where recursive models are arranged horizontally instead of vertically. In the further study four WASAN models were built of horizontally dependent systems showing how waste was caused by an upstream system. Each model showed a different perspective of the waste and how to manage it. Relying on analysis of a single system didn't represent the situation. Therefore using the principles of recursion the horizontal dependencies across the meta-system were modelled. This showed the emergent properties of the meta-system and more accurately identified root causes so that problems can be addressed.

7.1.4 Development of theory across PSMs

This thesis has made a contribution to our understanding about how theoretical contributions are transferable across a common framework. It is outlined below.

1. *Showing a commonality in the underpinning framework of PSMs*: Chapter 6 showed how recursion had been used as a model building tool to understand the interconnections of the expanded system in the further study. The definition of recursion was identified and it was shown that the applicability of recursion as a contribution was not limited to WASAN. The

contribution was to a framework of ideas that underpinned WASAN and other PSMs. Therefore recursive model building (horizontal and vertical) was transferable to SSM and SODA. This shows a commonality in the framework underpinning these approaches.

7.1.5 Development of WASAN

Chapter 4 showed how, through the development and application of the four pillar framework, WASAN shares the common features of PSMs. Some of these could be shown before this research project, such as Q3 “does the approach build a model in a facilitated way?”, while others needed to be developed in this research project, such as Q10 “Is the model building process generic so that it can be transferred to multiple problem contexts?”. Having shown WASAN to share the features of PSMs the next task was to show WASAN shared a common philosophical, theoretical and methodological framework with PSMs. This was done by identifying theoretical contributions in WASAN which were transferrable to the established PSMs. This was achieved by showing how horizontal recursion was developed in Chapter 5 & 6 in WASAN. This theoretical contribution was then shown in SSM and SODA. This was only possible because there is a common underpinning, philosophical, theoretical and methodological framework across WASAN, SSM and SODA. These two elements of proof lead me to conclude that WASAN has shown the required proof to be considered a PSM.

7.1.6 Impact of research

As a researcher in a Business School it is important that research goes beyond making theoretical and practical contributions to the PSM research community and has impact for the clients and research partners . Therefore, it is worth acknowledging here the impact this project had upon the UK Police Force. As identified in Chapter 1 the research project was conducted as part of a 2 year knowledge transfer partnership (KTP), the estimated year on year savings this project identified and implemented was estimated at £819,000 in *Customer Contact*. The savings attributed directly to WASAN are not included in this figure as they were very difficult to quantify and the research project was concerned with identification of recommendations to be implemented by the force. However the feedback sessions identified the benefits of looking at the problem situation in a new way. *"So just to ask us the question, we've probably never ask ourselves that question have we about well what do we think is waste and what affects the performance. So I think that is useful looking at the front end, you know there is stuff we perhaps don't have control of but can we have an impact on it" [Chief Inspector in feedback meeting].* The UK Police Force also liked how the whole process was packaged into a single methodology "*it's quite good someone comes in and brought it all together if you like 'cos I think we all do it without knowing it discussing individual things on different shifts but it's never brought together and presented in a way forward if you like so that was good"* [Control Room Supervisor].

7.2 Looking back – What did I learn about the research process?

Ph.D. is colloquially referred to as a research apprenticeship, the aim is to learn and develop the research craft skills required to manage and run research projects. With this in mind it is worth reflecting upon my own learning during my research apprenticeship. Conducting this research within an action research setting gave me the opportunity to learn about the context, methodology and underpinning framework of this work. In addition to this Hult & Lennung (1980 p.242) suggest in their definition that action research should "enhance the competence of the respective actors". Therefore as I was leading the research I should expect a great deal of learning. Below are three areas in which I feel I have learnt about the research process which are not explored in the thesis.

7.2.1 Learning points

First, was how to identify theoretical contributions through the research process. Working full time at the UK Police Force meant balancing the practical needs of the client with the needs of the Ph.D. That is, the need to save money and improve service delivery to the public for the UK Police Force and the need to generate theoretical contributions of interest to the research community. Over the course of 2 years with the force there were a plethora of problems and issues that could have been the focus for the Ph.D. However it was important to choose a context where it was possible to find novel contributions to the theory of PSMs. Working inductively in an action research setting meant reflecting critically on the research and contrasting this with the existing literature base. It was important to balance the need to develop theoretical contributions and the need of the UK Police Force practical impactful research outputs.

The second key learning point was the importance of the relationship between myself as the researcher and the participants and gatekeepers for the research study. Fundamental to this was trust, over 2 years working with the UK Police Force we had established a strong working relationship based upon mutual trust. This meant they were willing to abstract staff from their normal duties for an interview for up to an hour at a time. They would have been unlikely to make such an investment in a piece of research if they did not trust me in getting the results they needed. This was represented during the Stage C focus group in *Call Handling* when a Superintendent and five other members of staff agreed to attend the session for approximately 90 minutes. Getting that level of commitment from senior members of staff would not have been possible without mutual trust.

The third key learning point is the critical eye which researchers must view the world through. I have learned as a researcher not to accept ‘facts’ at face value, but always ask what was the research process that lead to this output. As a researcher I constantly challenge myself and my own beliefs along with those around me. Asking the questions why and how of all evidence that is presented to me. It is the change in this critical eye that I notice most prominently in myself and my peers who have embarked upon a Ph.D. at the same time that I have. This change happens over time as we progress through the research apprenticeship and I am sure over time it will develop further.

7.2.3 Limitations of the research

There are limitations to the understanding this research project can give to the philosophy, theory and methodology of PSMs. The limitations are predominantly related to the external validity of the research and are discussed below.

The generic applicability of WASAN was demonstrated by applying it to one new context (the UK police force), this in itself would not show that WASAN is generically applicable beyond the two problem contexts it has been successfully applied to (Nuclear and Police). However the research sought to understand the developmental process underpinning the generic development of WASAN. Establishing the difference between contextual and methodological elements allows the project to suggest WASAN will be generic in other contexts if the contextual elements are adapted as required and, further to this point adapting these contextual elements would not compromise the ability of WASAN to translate its aims (philosophy) in to practice. Due to the scope of the project and the difficulty in gaining the access required to do a full scale implementation of WASAN in an entirely new problem context testing these assumptions was not possible.

The project was also unable to fully test other fringe PSMs to identify if they had the features of PSMs as identified in the four pillar framework. Visioning Choices was examined on the bases of a reported case by O'Brien & Meadows (2006). This is not the same as the comparison between the framework and the approach being conducted by someone who has used the approach.

Finally the project must not act as a constraint on the development of the theory and methodology of PSMs. Chapter 2 showed how the development of OR and then PSMs was in response to a practical need and a new type of problem. PSMs must be able to retain their plurality if new needs arise which would force a change in the framework. That is not to say PSMs must be all things to all people, however if a real need arises that does not fit the framework but is still in keeping with the underpinning philosophy of PSMs then affected elements of the framework must be reconsidered. Exploring this is beyond the scope of this Ph.D.

7.3 Looking forward – Journal papers from this research project

Below are the two abstracts for the papers submitted to European Journal of Operational Research that have been developed during this Ph.D.

7.3.1 A framework to assess what is a problem structuring method

Abstract

Problem structuring methods are a class of qualitative operational research modelling approaches first developed approximately 40 years ago. Different definitions of PSMs have been proposed, some focusing on the types of problems that PSMs typically address, others on how they 'solve' these problems. Despite this, there is no clear framework for what characteristics need to be present in an approach to warrant it being regarded as a PSM. This presents a challenge to the classification of new/candidate PSMs and the development of existing PSM methodology as without known parameters the PSM family may be weakened by approaches/additions that do not share core features. This paper presents framework to delineate PSMs from traditional OR approaches leading to expansion of the field within explicit, rigorous and known parameters. The framework assumes PSMs make different philosophical assumptions to traditional OR and so examines the ontological, epistemological, axiological and methodological assumptions an

approach makes by posing 15 questions to determine if an approach is a PSM. The effectiveness of the framework is tested by applying it to eight OR approaches to see if it successfully delineates PSMs from non-PSMs.

7.3.2 Modelling recursive systems using Soft OR: The concept of horizontal recursion

Abstract

This paper considers the concept of recursion in Operational Research (OR) where it is used to explain how real world systems are embedded in wider systems. For OR modelling, recursion determines how the same system properties are replicated across different hierarchical units meaning that they should be amenable to the same analytical conventions. Thus, a model is built at one level of a system (one level of recursion), perhaps whilst integrating it with equivalent models of higher and lower hierarchical levels. While this views recursion as hierarchical, other fields use the term without this assumption and as a way to explain relationships in a vertical (hierarchical) or horizontal (continuous) sense. This paper uses these other contexts to develop criteria for defining recursion as vertical or horizontal and uses these to explore the potential of horizontal recursion for Soft OR model building. A case study of a Police Customer Contact Department explores how horizontal recursion may be analysed using a Soft OR method called WASAN.

In addition to the above two papers which have been submitted to the European Journal of Operational Research is the below paper which is yet to be written but based largely on Chapter 4.

7.3.3 Understanding the development process of a generic approach

Abstract

This paper considers how bespoke single use approaches can be developed so they are generically applicable. This paper identifies two classes of elements that

need to be present for an approach to be considered generic. First, are methodological elements, these translate the underpinning philosophy of an approach. These elements need to be replicated across all uses of the approach. It is these elements which underpin why and how the approach is used. Changing these elements would result in a shift of the fundamental assumptions of the approach being used and therefore would constitute a new approach. Second the contextual elements, these are those elements which can adjust depending on the context. To translate the methodology into new contexts there needs to be a degree of flexibility in how the approach is applied, this comes from these contextual elements. A case study of a Police Customer Contact Department explores the development of the Soft OR method WASAN to identify what structures and features need to be present for an approach to be generically applicable.

7.4 New research gaps

As identified in Section 7.2 this thesis has made several contributions to knowledge. Making these contributions has opened new research avenues which can be addressed in future research projects, these are outlined below.

1. *Developing theoretical contributions across PSMs*: The introduction to this thesis identified that research into PSMs tends to only focus on one approach. The development of the four pillar framework means research can focus on an aspect of the framework. These contributions to the framework can then be tested across multiple PSMs. This type of research will contribute to building an accepted philosophy, theory and methodology of PSMs.
2. *Horizontally recursive model building in other PSMs*: Chapters 5 and 6 identified horizontally recursive model building as a tool which can be used in PSMs. Its use has been shown in WASAN, SSM and SODA. Further

research could be conducted to use both horizontal and vertical recursion as a model building tool in other PSMs or fringe PSMs.

3. *Identifying if approaches are PSMs*: Chapter 1 identified ten approaches that have been developed since 2000 which make varying claims of being PSMs. The four pillar framework developed in Chapter 2 was used to show WASAN exhibit the features required to be considered a PSM and that Visioning Choices exhibited most of the features required to be considered a PSM. This could be extended to consider some of the remaining approaches identified in the introduction of this thesis.
4. *Developing bespoke approaches using smart bits and the four pillar framework:* This thesis has argued that developing methodology using smart bits could prove a strong defence against the paradigm incommensurability thesis. The use of smart bits to develop bespoke approaches fit for specific problem contexts could open up a more dynamic approach to methodology development in PSMs. Using an action research framework it would be possible to enter a problem context and develop a bespoke approach comprised of the most appropriate smart bits. Any qualitative OR approach could be grounded in the four pillar framework to make sure they had considered if each of the features of PSMs were relevant to the specific context. This type of research would be novel, and while first use approaches would not have all the features of PSMs as they would not be generic to multiple contexts the dynamic way of working would be a novel contribution to the theory surrounding PSMs.

7.4 Summary of Conclusion

This chapter has summarised the contributions this thesis has made to theory and practice. These contributions were categorised into: the features of PSMs; development of methodology; horizontal recursion; development of theory across PSMs; and, the impact of this research. In addition to this, the chapter reflected upon how I have developed as a researcher through this process. The chapter also looked forward identifying three papers which can/have been written based upon the research in this thesis. It also identified future directions for research that are now possible because of the contributions from this research.

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